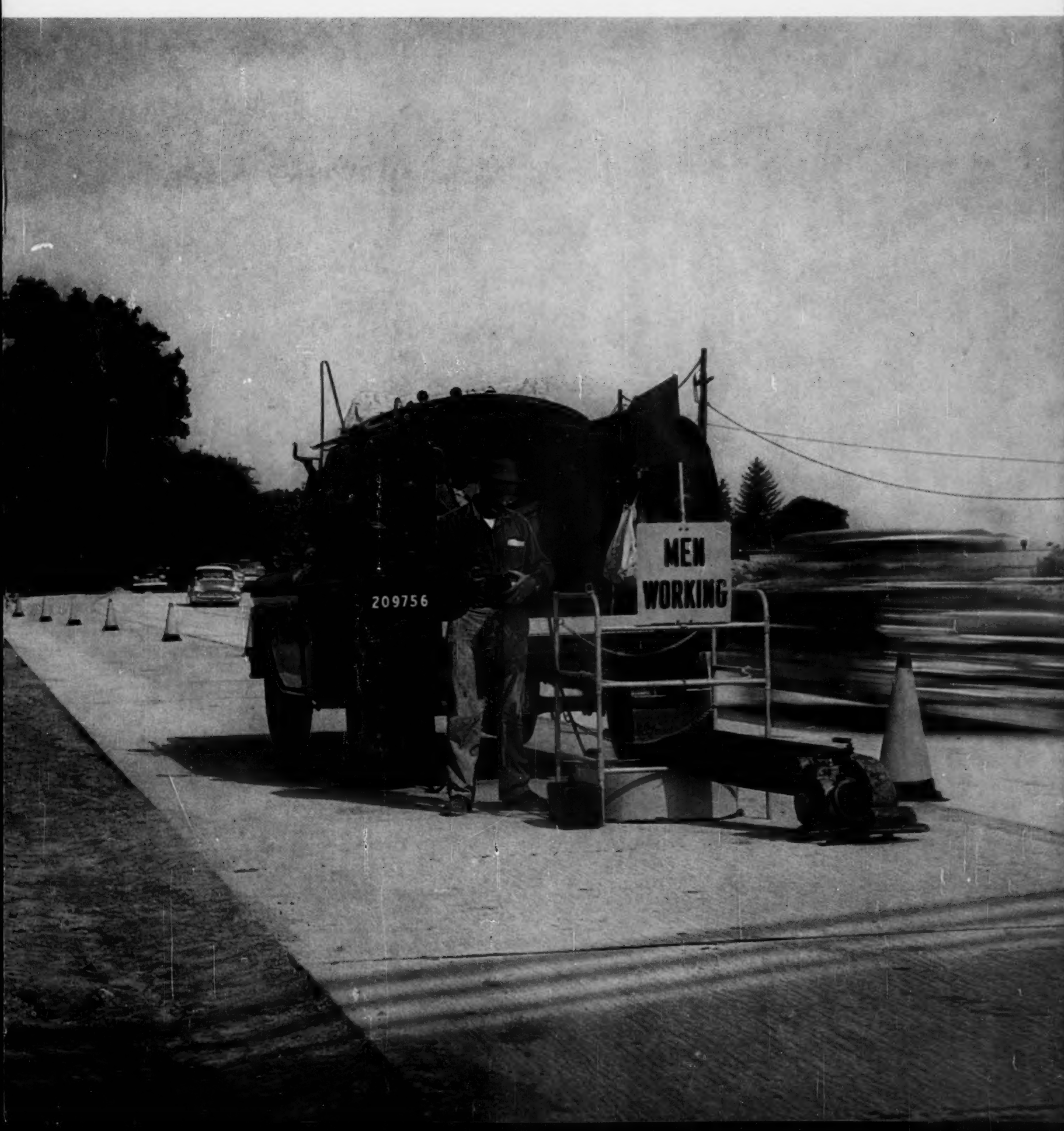
January 1961

Bell Laboratories

RECORD



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Bell Laboratories **RECORD**

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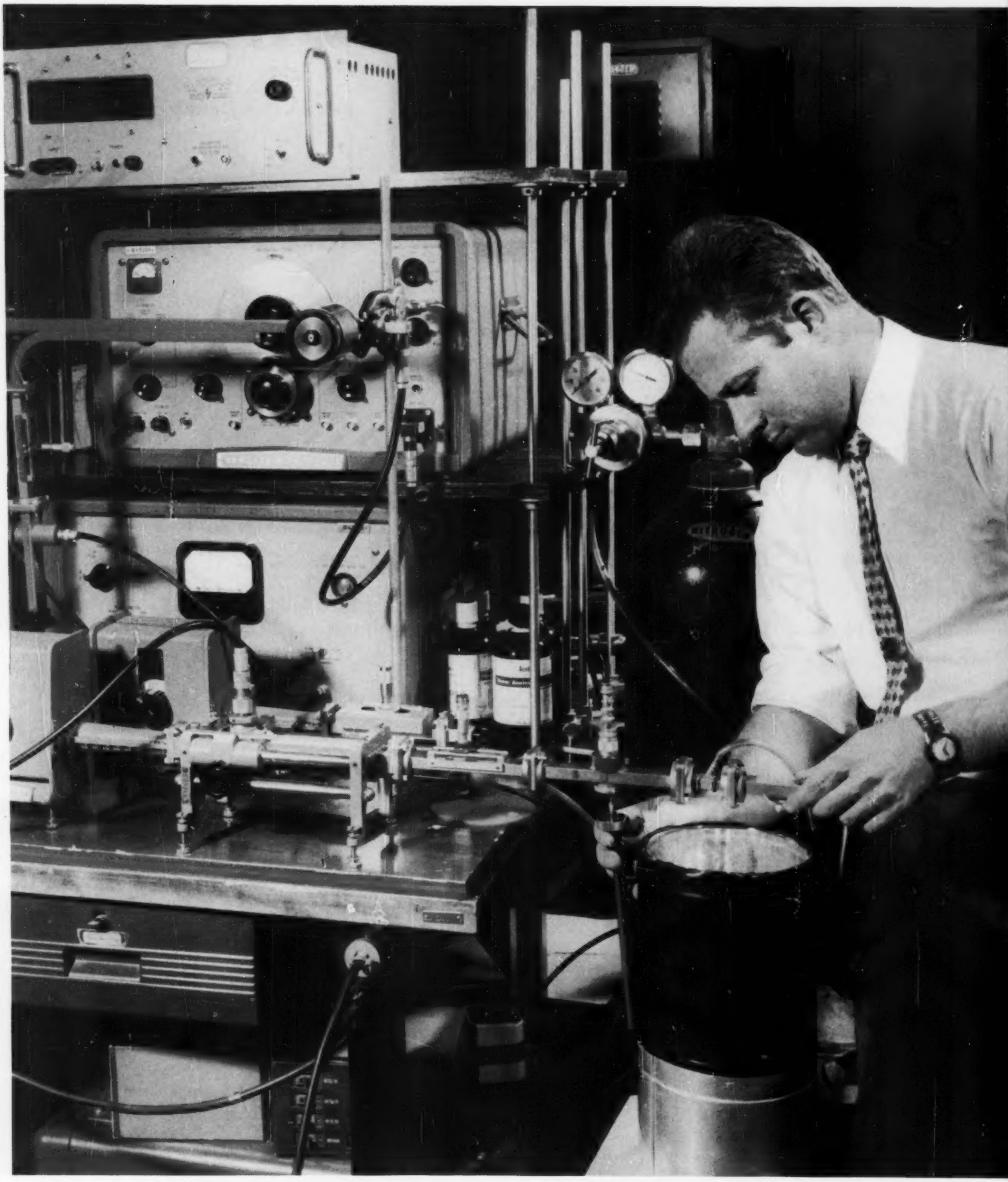
Contents

Cover *A telephone workman uses a hot-wire indicator to check for presence of explosive gases in manhole. Blower (foreground) assures adequate air supply. Manhole guard, flasher, safety cones, and flags protect workman from highway traffic. (See page 10.)*



I. Dostis inserts diode, at end of rod, in microwave-diode test apparatus. Flask, right, is used for measurements at low temperatures, since thermal noise in diodes is important in some applications.

One of the most important outgrowths of the electronic revolution, started at Bell Laboratories with the invention of the transistor, has been new and more versatile semiconductor diodes. By using the theories, new materials, and advanced techniques of modern semiconductor technology, diode designers at the Laboratories have shown that . . .

J. H. Forster and R. M. Ryder

"Diodes Can Do Almost Anything"

The title above is a slight exaggeration. Even the developers of new semiconductor diodes might admit this. The statement is true, however, in a sense peculiar to electronic engineering—namely, semiconductor diodes now exist that can perform practically all the basic circuit functions, both active and passive.

More specifically, this means that existing diodes, in reasonably straightforward circuits, can perform such important electronic functions as: amplification, switching, rectification, generation of high-frequency power, logic, measurement of light intensity, conversion of light to electricity, tuning other networks, triggering, protection (voltage limiters), voltage-referencing, and modulation. A major factor leading to this versatility has been the enormous expansion of the capabilities of semiconductor diodes through the application of the same knowledge and techniques that have led to today's highly developed transistors.

There is some poetic justice in the fact that diodes should share the benefits of today's expanding semiconductor technology with transistors, since the practical utility of both these devices in the communications field has provided strong motivation towards research on fundamental properties of semiconductors. The influence of the diode came first, when, during World War II, the successful use of point-contact diodes at microwave frequencies provided a powerful stimulus for an intensified study of semiconductor crystals. Continuation of these basic studies at the Laboratories made possible the invention of the transistor by J. A. Bardeen, W. H. Brattain and W. Shockley in 1948 (RECORD, *August*, 1948). The dramatic advent of this amplifying semiconductor element provided further stimulus to semiconductor research and technology, which made possible improved single-crystal materials, better design and processing techniques and large area, high-quality, p-n junctions. The application of this knowledge and technology to produce the versatile transistors of today is a well known story. Less familiar is the equally interesting history of how the application of this expanding semiconductor technology to diode development led to new levels of performance and even extended diode capability to completely new electronic functions.

By elaborating on this theme—the impact of the new semiconductor technology on diode development—this article will survey briefly some of the major trends in the expansion of diode performance and capabilities. Because the basic properties and resultant versatility of semiconductor diodes derive from the action of a p-n junction (RECORD, *June*, 1954), let us start by examining this action briefly.

Basic Action at a p-n Junction

Semiconductors like germanium or silicon can be made to conduct electricity by charge carriers, which can be either negative electrons (n-type) or positive "holes" (p-type), depending on how the semiconductor is "doped" with impurities. In a single crystal, a "p-n junction" is formed where the two kinds of doping adjoin. Because of their thermal energy, the holes tend to diffuse into the n-type material and the electrons into the p-type. However, after an exceedingly small fraction of the populations have diffused across the junction, an electrostatic potential or "barrier," is built up and opposes further diffusion. This very small equilibrium potential is the "contact potential."

If the equilibrium is disturbed by an applied potential that makes the p side positive, then by that much the opposing potential is reduced, and more carriers, both holes and electrons, can cross the barrier. The current that crosses this barrier is dependent upon and rises quite rapidly with the applied potential. The relative ease of current flow leads to calling this positive-bias condition the "forward direction." Forward current consists of "minority carriers"—that is, holes diffusing into the n side and electrons into the p side. These minority carriers are usually greatly outnumbered by the resident "majority carriers" of the other type. But in well made single crystals, the minority carriers may persist for a "lifetime" of many microseconds before they disappear by "recombination" with an equal number of majority carriers.

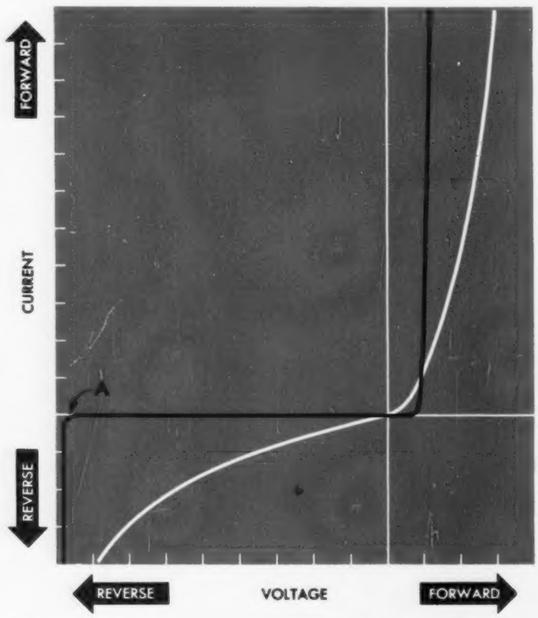
By contrast, if the equilibrium of the junction is disturbed by a voltage in the "reverse" direction (p side negative), then the opposing contact potential is increased. In this direction, minority carriers will be urged across the junction and "collected" into the type of material in which they naturally belong—that is, where they are "majority" carriers. However, the number of minority carriers is normally small. Consequently, the reverse current is low; at one volt it may be only a billionth of the forward current.

This very great difference in magnitude between the forward and reverse currents that cross a p-n junction gives rise to one of the fundamental properties of a semiconductor diode—rectification, or the ability of the device to make a current virtually unidirectional. The action at a p-n junction is also vital to two other basic properties of diodes: controllable electrical capacitance and photosensitivity.

Both point-contact and junction diodes (rectifiers) exhibit the phenomenon of rectification. The current *vs.* voltage curves below show this property for typical rectifiers of both types. So far as rectification is concerned, the improvement furnished by the new diodes, though large, is only quantitative. There are, however, some useful properties of the new diodes which lead to qualitatively different applications. The first of these is the sharp, reverse-"breakdown" effect (RECORD, *February*, 1958) used in the design of voltage limiters and reference diodes.

In a rectifier diode, the reverse current is very small, often much less than a microampere, until the reverse voltage is increased to a critical value, as at point A in the curves. Beyond this so-called "breakdown voltage," the current rises rapidly. Actually, it may increase as much as six orders of magnitude with a rise of only a few tenths of a volt.

Breakdown usually occurs when the minority carriers being collected across the junction receive sufficient energy from the applied potential



Black line is current-voltage characteristic of p-n junction diode. White line is that of point-contact diode. Breakdown occurs at point A.

This experimental microwave amplifier uses 16 junction diodes in series on its ground plane. Other circuitry is shown on the bottom of other plane.

to free the valence electrons of the material by impact ionization. An electron freed in this way then becomes a charge carrier, and so does the positive hole left behind in the valence structure. In other words, a hole-electron pair has been created by impact ionization. When the reverse potential is sufficient, these new carriers may ionize others, leading to an "avalanche," or rapid increase, of current, as shown in the curves.

Importance of Controllable Capacitance

Another basic property of the p-n junction—controllable electrical capacitance—is useful in the design of diode tuning elements and in the development of "varactor (VARiable reACTOR)," or parametric, diodes (RECORD, *October*, 1959), which show promise of becoming important as a new class of low-noise amplifiers. In such semiconductor diodes, two kinds of capacitance may be important—dielectric capacitance and storage capacitance.

The first of these is the dominant p-n junction capacitance at zero bias or when a moderate reverse bias is applied. In this case, the material immediately adjacent to the junction is "swept" free of carriers. This swept material behaves much like an insulator. And when additional reverse bias is applied, the width of the swept-out region increases, as shown in the illustration on page 7. Since almost all the applied potential appears across it, the region acts very much like a parallel-plate condenser, with the separation of the plates corresponding to the width of the swept-out region. Accordingly, this region exhibits a dielectric capacitance calculable from its dimensions by the usual capacitor formula. Since the width of the space charge region is voltage-dependent, this dielectric capacitance is electrically variable. This "variable reactance" is a property essential for varactor diode amplifiers.

The other capacitance-like property of diodes—storage capacitance—becomes important under forward-bias conditions. Minority carriers injected into the material have a finite lifetime, so that if the potential is quickly reversed, some of them will be swept back into their natural home in the p and n sides of the junction. These returning carriers do not contribute to the direct current, but rather constitute a capacitive current, whose magnitude depends on the forward current before the potential was reversed. For appreciable forward currents, when the carrier lifetime is sufficiently long, storage capacitance is normally much larger than dielectric capacitance. Moreover, it depends on forward current, and therefore shows a rapid (exponential) increase with voltage, as indicated by the curve on page 7. These controllable capacitances favor the junction diode as a variable-capacitance element that has a low loss, even at microwave frequencies.

The storage capacitance property, because it depends on minority-carrier lifetimes, may affect a diode's rectification efficiency at high frequencies, and it may also limit the speed of switching diodes. However, "minority-carrier storage" can be controlled to a considerable extent because the lifetime of these carriers can be drastically reduced by introducing controlled chemical impuri-

ties, by damaging the crystal lattice with electron or ion bombardment, by nuclear radiation, or by simply twisting the crystal while it is hot and plastic. Junction diodes have been made which show storage times less than a thousandth of a microsecond yet still have a high rectification efficiency.

Photosensitivity is another useful property of semiconductor junctions, and it also depends on minority-carrier lifetime. When radiation of sufficient energy is absorbed by a semiconductor, valence electrons may be excited into the conduction band, thus creating a hole-electron pair. The holes are minority carriers in n-type, the electrons are minority carriers in p-type. If appreciable numbers of minority carriers can reach a junction by thermal diffusion during their lifetime, they can modify the junction characteristics. For instance, if the junction is reverse-biased, the minority carriers are collected to give a current closely proportional to the light intensity. In fact, such photocells are useful secondary standards for measuring light intensity.

Because of the contact potential, there is an electric field across the junction when it is unbiased. Consequently, carriers generated by the action of light are still collected at the junction even if no bias is applied, and one has a "solar battery" (RECORD, *July*, 1955), which can convert sunlight directly to electric current at a potential approaching that of the p-n junction.

How Junction Properties Have Been Used

These properties — rectification, dielectric capacitance, storage capacitance and photosensitivity — are the most important properties of p-n junctions, in that they have been reduced to extensive practical application in production diodes. With these major properties of p-n junctions as background, let us get back to our main theme—how the new semiconductor technology has affected diode development.

Chronologically, the first contribution from semiconductor technology was high-purity, single-crystal material. Even without improvements in device fabrication, this advance facilitated making diodes of the same type much more nearly alike. Purer single-crystal material also made available a somewhat greater range of designable properties because it contained fewer physical defects. Later contributions included a considerable variety of techniques for making p-n junctions. Two important methods of fabricating this heart of the diode are solid-state diffusion (RECORD, *December*, 1956) and alloying (RECORD, *March*, 1959).

By using these materials and techniques in combination with further study and a better understanding of the inherent nature and properties of the p-n junction, designers have greatly extended the performance, capability and versatility of junction diodes. Broadly speaking, the improvements they have made in diode characteristics can be divided into six basic categories:

- Increased size and power through the use of junction techniques and improved single-crystal material
- New junction characteristics not attainable with older techniques
- New combinations of features in a single diode
- Improved and more reproducible electrical characteristics
- Improvements resulting from new structures
- Improvements resulting from applications of new materials

In the first category, power rectifiers were the first application of the new semiconductor art to increased usefulness of diodes. In contrast with the older point-contact diodes, which could handle only milliamperes, new junction rectifiers are available in ratings up to hundreds of amperes. This improvement results from the increased junction area made possible by the uniformity of the diffusion or alloy techniques.

Some pre-transistor selenium diodes with large areas also existed. However, a modern silicon junction rectifier can be made to stand a peak inverse voltage of at least several hundred volts, and developmental units have withstood up to 3000 volts. This improvement is due to high-purity, single-crystal material, and compares with 15 volts per disc for selenium diodes. In terms of power-supply design, use of the newer rectifiers can result in as much as an 80 per cent reduction in power loss in the rectifiers, and permits a corresponding reduction in size. There are also uses for germanium rectifiers, which, having lower forward-voltage drops than the silicon units, are more efficient for low-voltage, high-current rectifiers.

Next to appear on the scene, and a good example of improvements in the second category, were the voltage-limiting diodes. These are useful in this application because of a new feature of the p-n junction characteristics—the sharp reverse breakdown. Since the breakdown voltage depends only on the conductivity of the single-crystal silicon and the diffusion program followed, these diodes can be made in a wide variety of voltage ratings with very good reproducibility. A variety of power ratings is also available, since

power handling depends largely on the wafer area and the thermal design. Compared to gas-tube voltage regulators, these diodes have greater life and reliability, although the variations in breakdown voltage with temperature are somewhat larger and may require compensation—with additional diodes, of course!

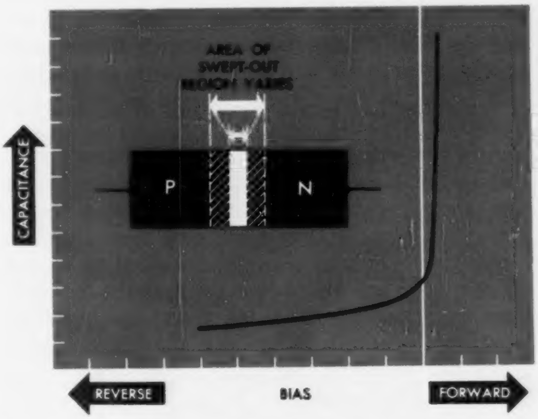
More recently, new techniques that make possible a combination of properties—our third category of improvements—have been applied to the development of high-speed computer diodes. The switching speed of a p-n junction may be limited by minority-carrier storage, whereas some of the older point-contact diodes exhibited much higher switching speeds. However, these fast point-contact diodes had inferior reverse characteristics, which made them poor switches. The ideal combination is sharp junction characteristics together with the switching speed of the point contact.

Diffusion techniques make such a combination possible through large-area junctions formed by diffusing boron into n-type silicon. This produces a p-n junction with low reverse current, high forward conductance and a reasonably high breakdown voltage. A further diffusion step takes care of the minority-carrier storage problem by introducing a well-controlled density of gold atoms, which act to speed up the recombination of minority carriers (decrease their lifetime). It is also necessary to decrease the size of the junction so that switching speed will not be limited by the time required for a large junction to charge up when reverse bias is applied. Junction size may be limited by ultrasonically cutting the diffused silicon into wafers with a circular mesa of small diameter.

Switching speed for a diode of this kind can be as fast as one billionth of a second, yet the reverse current drawn can be one hundred to ten thousand times less than the reverse current for a point-contact diode. These new computer diodes have improved speed, forward conductance, and reverse impedance. They are well suited for use in low-loss, high-speed logic circuits.

Other functions, such as modulation or frequency shifting, can be based on the non-linear resistance of diodes, a property of both old and new. Here, however, the junction units are often superior because the characteristics are more controllable and are accompanied by substantially less incidental ohmic (parasitic) resistance. Thus, post-transistor techniques make possible improvements in our fourth category—improved and more reproducible junction characteristics. Furthermore, some high-lifetime diodes (germanium alloys) can be built with voltage-current characteristics that are quite accurately logarithmic over as much as six decades of current. These germanium-alloy diodes make not only superior modulators but also good instrument or analog-computer components.

Improved photosensitive diodes also made their appearance as a result of the new technology, first using grown germanium junctions, and later diffused silicon junctions. These units had two interesting new properties. First, their response under bias could be made almost equal to one electronic charge per quantum of light absorbed, so that the diodes could be used as secondary standards for measuring light intensity. Second, their efficiency in converting light energy directly to electrical energy was very high; high



Curve shows how total junction capacitance varies with bias. Diode model, inset, shows how this capacitance varies with area of "swept-out" region.

enough to suggest possible application as a solar-energy converter. Efficiencies exceeding 10 per cent have been achieved, and a battery having the area of a LIFE magazine cover can have a quite respectable power rating (22 volts, 500 milliamperes in direct sunlight). To make these attractive technical possibilities economically competitive, however, still requires considerable reduction in cost of material and fabrication.

Also in this category of improvements is perhaps the most surprising new diode development—low-noise amplifiers at frequencies up to the microwave region. These diodes surpass in performance not only transistors, but also the best low-noise vacuum tubes, and even approach the liquid-helium-cooled masers (RECORD, *July*, 1958; *May*, 1960) in excellence of performance at some frequencies. Low-noise diodes depend on the fact that a periodically time-varying reactance can

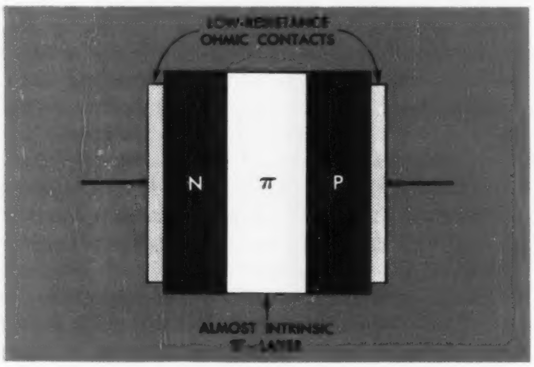
amplify, a fact discovered by the famous British physicist Lord Rayleigh 80 years ago.

Although the structure of these diodes is often very similar to that of the fast computer diodes, it is a different feature of the junction that dominates their electrical behavior. These varactors make use of the fact that the dielectric capacitance of a reverse-biased p-n junction can be made to vary with voltage, as shown in the illustration on page 7. It is the improved and more reproducible characteristics of the semiconductor junctions that make the junction varactor useful for amplification at high frequencies.

Varactors also have uses other than low-noise amplification, although these uses are also derived from the fact that they exhibit a voltage-controlled capacitance. They can be used to adjust the tuning of resonant circuits, oscillators, filters, and the like. Furthermore, varactor diodes make excellent harmonic and sub-harmonic generators, and might in the future be used as computing elements.

Another outgrowth of the new semiconductor technology, classified in our list as new structures, are triggering-diodes—four-layer devices having three junctions rather than only one (RECORD, *June,* 1959). These are still classified as diodes, though they are also two-stage transistor amplifiers with positive feedback from their internal electronic coupling. They can therefore exhibit controlled behavior much more complicated than ordinary single-junction units. P-n-p-n diodes can serve as electronic switches having both high speed and a very high on-off ratio.

The new diffusion techniques, together with the availability of high-purity single crystals have also made possible the intrinsic-barrier diode, or n-i-p diode (BSTJ, *May,* 1956), a new diode structure. This diode can be made by diffusing n- and p-type impurities into high-resistivity silicon



Simplified diagram of the n-π-p diode, showing the relative size and position of the π layer.

(called i-type). The high-resistivity silicon is often lightly p-type—designated π type—so it is more accurate to speak of an n-π-p diode.

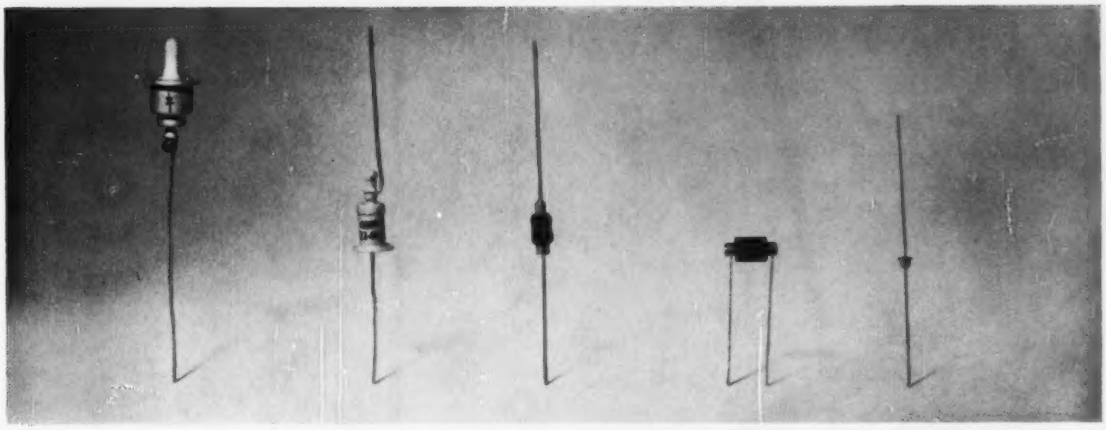
The n-π junction and the π region (*see diagram below*) have properties that make this kind of diode useful at microwave frequencies. At the n-π junction, the space-charge layer is relatively wide; much wider than that associated with a junction between n-type and p-type silicon of heavier doping. Thus, the n-π junction area can be large without having an excessive junction capacitance. Actually, an n-π diode with 100 times the area of a small varactor diode might have the same capacity. Although the π layer has a dielectric capacitance, this also can be made to be of the same order of magnitude as that of the n-π junction. At low signal-power levels, the n-π-p diode approximates fairly closely resistance and capacitance in series for which the cutoff frequency (varying inversely as capacity times resistance) can be as high as 30,000 mc.

Other Properties

As a protective device, when shunted across a transmission line, the diode will transmit power with low loss, even at microwave frequencies, so long as the power level is low. If incident power increases, however, the capacity of the n-π-p diode increases and its resistance decreases. The diode then acts, both by reflecting and by absorbing power, to prevent transmission of power. Thus, the n-π-p diode is a very good protective limiter, or switch.

Since it can be 100 times larger in area than a varactor, it can readily dissipate much more power, and is therefore a higher power device. A diode of this type has been designed that has a zero-bias capacitance of only 5 micro-microfarads, yet can carry a rated current of over 10 amperes, and is usable as a protective switch at UHF frequencies to reflect available CW power of well over half a kilowatt.

Our title claims that "diodes can do almost anything." One of the things which perhaps is not quite out of the "almost" category is that well-known *Ultima Thule* of the semiconductor field, the direct generation of microwave power from dc excitation. Two diode structures are of interest here. The first is the transit-time, space-charge diode postulated at the Laboratories by W. Shockley and W. T. Read. This device makes use of the fact that at high frequencies the phase delay accompanying the transit time of electrons across the p-n junction would be expected to lead to oscillation. In an ideal semiconductor material this is true. But nearly all practical junctions exhibit local microplasma



Because diodes are so versatile, they naturally come in all sizes and shapes. Shown here, at approximately life size, are five typical diodes now being manufactured by Western at Allentown.

breakdown. That is, breakdown does not occur uniformly over the whole p-n junction, but rather occurs locally in small, discrete regions. With improved junctions (and materials) it might occur uniformly, since generation of microwave power in avalanche breakdown has been observed.

The other proposal is the tunnel diode, first suggested by the Japanese physicist, Leo Esaki. Its properties also arise from its structure—a rather unique type of p-n junction. A diode of this kind can be made by fabricating a p-n junction between two very heavily doped regions of certain semiconducting crystals. Under certain bias conditions, electrons can penetrate the space-charge layer at the junction by a process of "tunneling," which is similar in nature to the way in which electrons can escape from a cold cathode in a high field. Tunnel diodes made at Bell Laboratories have already been used to generate oscillations at over 100,000 mc per second.

Although the characteristics of the Esaki diode are at present such that it is a relatively low-power device, it promises to be extremely versatile. Its negative-resistance characteristic makes it potentially useful as an oscillator or amplifier. The inherent speed of tunnel diodes is high, and this feature in combination with its other unique properties suggests its use as a very fast and versatile computing element.

The final category in our broad classification of the sources of diode improvements is materials. Improvements in diodes due to new materials or materials processing techniques apply almost across-the-board in all of the examples cited. It is also fair to say the new "III-V" semiconductor compounds—made from combinations of elements in the third and fifth groups of the periodic table—will probably make further improvements in the performance and capability of almost all kinds of diodes.

In spite of the progress that has been made in expanding the performance and versatility of semiconductor diodes, unsolved problems remain. Compared with the older point-contact diodes widely used for microwave reception, the junction varactor diodes make better receivers at the lower microwave frequencies. However, for higher frequencies, above approximately 10,000 megacycles, the point-contact diodes are still superior; in particular, the improved gallium-arsenide diodes recently produced at Bell Laboratories by W. M. Sharpless. Furthermore, the junction-type computer diodes mentioned above, in spite of their excellent and highly reproducible rectifying characteristics, still have lower switching speeds than the microwave point-contact diodes.

Finally, no matter what a device costs or how excellent its characteristics may be, it will always be more widely used when it costs less. The key here is simplicity of fabrication. Diffusion techniques, applied to diode manufacture, have already led to simpler processes and therefore substantially lower costs, and further decreases in cost are expected with rising production levels.

Thus, despite the extensive developments reviewed here, there are still improvements to be made in performance, uniformity, and manufacturing control by further application of the newest semiconductor technology. In addition, further advances in knowledge, new materials and new structures can be expected to continue to help the semiconductor diode "do almost anything" in the field of electronics.

Engineering fo

The first reported telephone accident occurred when Alexander Graham Bell spilled acid on his pants and called for Mr. Watson. Even with that experience and his clairvoyant prophecy of modern telephonic communication, it is doubtful if Dr. Bell had any conception of the safety hazards that would attend the realization of his dream. Nevertheless, the System that bears his name has conducted a ceaseless, relentless war on accidents since the beginning of the business.

The Bell System was one of the first industries to reject the philosophy that a workman who accepts employment must also accept the hazards associated with that employment. Instead, by every means at its command, the communications industry has made its field the safest in the world. The Bell System has time and again received the National Safety Council's highest annual award for its part in achieving this very excellent safety record.

The fiercest fighting in this all-out war against accidents has been, and still is, in the outside plant sector where the exposure to hazards is greatest. It is this part of the telephone plant—between the central office and the customer—that most concerns the engineers who design tools and equipment used by telephone workmen.

W. S. Apgar depends on climbers, body belt, and safety strap as he tightens lashed cable support.

The work of a group of engineers at Bell Laboratories has helped to make the communications industry the safest in the world. These engineers assure the safety of telephone equipment and personnel in all kinds of weather and emergency situations.

E. L. Alford

Safety in the Outside Plant

This concern has been evident since the early days of the telephone art. Time, conditions, and methods have changed over the years, but for the person involved in an accident, loss of earning power, pain, hospitalization and the effects on families, are the same as always. Today, although a telephone workman need no longer fear being kicked in the head by a horse or a mule on a construction job, he can suffer similar consequences by entering an explosive atmosphere in a manhole or by touching an energized street lamp bracket on a "joint-use" pole.

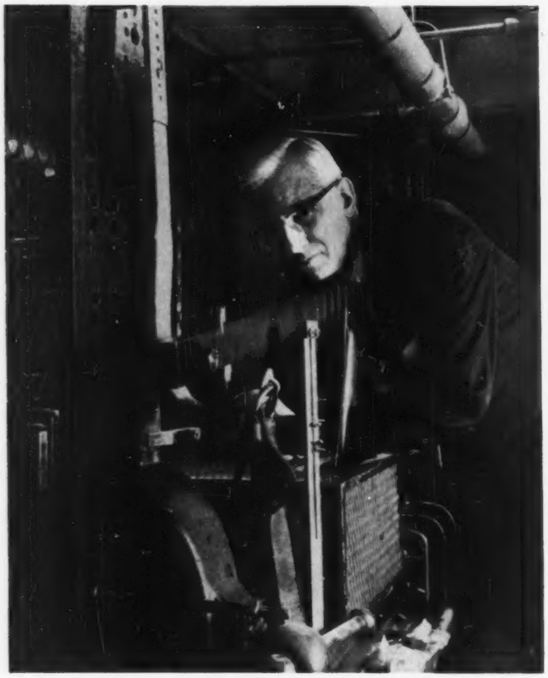
With increased efficiency made possible by modern work-saving tools, more work is being done by fewer people. Instead of five- to nine-man crews, there are many two- and even one-man crews. Solo splicers—those working alone more than half the time—have increased from about 2 per cent of the splicing force in 1951 to an estimated 75 per cent in 1960. Similarly, small line crews (generally two men) account for about 84 per cent of the line-construction forces. The reduction in crew size and resultant supervision on a group basis has made ever more necessary a constant alertness to hazards and the necessity of providing safer, more efficient, and lighter weight tools.

This article considers the three general categories of tool equipment used by the outside-plant forces. First are the functional tools, ranging from the prosaic screwdriver through climbers, rubber gloves, body belts, safety straps, and ladders to electrical test sets used for locating circuit faults.

In the second category are tools used to determine whether a job can be performed without danger. These tools enable a workman to detect certain hazardous conditions. The B-voltage tester, which indicates the absence or presence of foreign voltages on telephone plant equipment, and the gas-detection devices used to ascertain whether a manhole contains explosive or toxic gas *(see cover)* are typical examples of this kind of equipment.

Equipment devised solely for guarding work areas for the protection of workmen and the public is the third category. Equipment of this kind may be manhole guards, warning flashers, warning flags, signs, barricades, flood lamps, and the like.

The prime requirement for all tools is that they function properly and safely. For instance, over the years a number of significant changes, all in the interest of safety, have been made in the design of climbers. A changed gaff angle contributes to a 50 per cent reduction in climber cutouts (accidental disengagements from poles), which for years accounted for 10 per cent of the lost-time accidents of Bell System plant men. A new alloy steel now provides a tougher, stronger gaff having a greater resistance to breakage and dulling. Until three years ago, climbers came in 13 sizes. Today, with adjustable climbers, there is only one size. This makes feasible precision sharpening by machine at centralized locations to eliminate hazardous gaff contours that were often the result



E. L. Alford observes climber, center, with strap coming from footrest, being fatigue-tested. Slight blur, center, is moving arm, which cycle-stresses adjustable climber to simulate use in the field.

of hand filing in the field. This program of precision sharpening is now under way at Western Electric distributing-house repair shops.

Rubber gloves meeting rigid material, mechanical, and electrical requirements must be returned from the field periodically for examination and electrical retesting by the Western Electric Company. This is done to insure the integrity of gloves on which a man's life may depend. Wood ladders are another item supplied to the Bell System under specifications prepared by the Laboratories. These specifications exceed the safety code requirements of the American Standards Association. In fact, they result in the finest product of the American ladder industry.

The 105-type test set for cable-fault location represents another functional tool with an inherent safety aspect of great importance. This tool, used for locating short, crossed, and grounded circuits, consists of an exploring coil assembled on a fiber glass pole; it is used with an amplifier and a headset. An insulated cord running through the hollow pole is connected to the amplifier, which is in turn connected to the headset. If there is a fault in the cable, a tone is sent over the defective conductors from the central office or a nearby cable terminal. As the workman moves the coil of the test set along the cable, it picks up this tone. A weakening or disappearance of the tone indicates the location of the fault.

In performing such tests, there is always the chance that the test set might contact adjacent power wires or energized telephone plant. Obviously, a man holding such a device, and with a receiver clamped on his head, must be adequately protected from electric shock from such chance contacts. Before the advent of 105 sets, such contacts sometimes had disastrous results.

In the 105 test set, the designers used every practical electrical and mechanical means to prevent such an occurrence. This set is not only engineered to withstand 10,000 volts without breaking down, but, as in the case of rubber gloves, it must be returned at regular intervals for inspection. At that time, it must pass the 10,000-volt test or be reconditioned so that it will.

The second category of tools mentioned earlier includes those used to determine whether a workman can do his job free from hazards which could cause injury or death. Typical of such tools is the B-voltage tester for detecting foreign voltages on pole lines jointly used by telephone and power companies, particularly vertical ground wires and street-lamp fixtures. This device consists of an insulated probe, with a toothed metal disc at the end connected to a small neon lamp. When the tester touches plant energized with potentials as low as 60 volts and as high as 7600 volts, the neon lamp glows. This voltage range covers all sustained voltages likely to be encountered in telephone

The spur-like "gaff" on a climber being checked for length prior to precision-sharpening at W.E. shop.

work. There are authenticated cases where the use of this device has prevented electric shock, if not electrocution.

Another tool in this category is the hot-wire gas indicator. This instrument indicates the presence of even a trace of explosive gas in a manhole. Since no explosion can occur when the concentration of gas is below the lower explosive limit, this instrument has a big safety margin. Other indicators detect the presence of carbon monoxide or oxygen deficiency.

The third category of outside plant tools encompasses a variety of devices that safeguard workmen and the public during construction and maintenance operations along streets and highways. This category consists of equipment designed primarily for guarding work areas.

Progress in Designing for Safety

Here, again, we note the progress in the development of safety equipment. Because of today's high-speed automotive traffic, workmen can no longer depend solely on kerosene lanterns with red globes for protection. Now, high-intensity, condenser-discharge-type flashers mounted well above the road are necessary both night and day to provide sufficient warning. Fluorescent red flags, reflective warning signs, brightly colored manhole guards, and safety cones are some of the other devices used to warn the increasing number of fast-moving cars.

The marked trend toward small crews and solo workmen, previously mentioned, has complicated the technical problem of meeting the frequently conflicting requirements of workman safety on the one hand, and portability and ease of handling on the other. For example, the strand-, pole-, and ladder-supported platforms used by the solo splicer must be light enough to be handled by one man and at the same time they must be structurally safe. Similarly, the tents, tent heaters, and a host of other items must be operationally safe, yet must be practical for use by one man working high above the ground. Solving such conflicting problems is a constant challenge to the ingenuity and experience of Laboratories engineers.

In the continuous struggle to prevent accidents, it is of prime importance that no stone be left unturned in designing safe tools, materials, structures, and equipment; furthermore, safe methods must be devised for their use. To this end, the Laboratories assists the American Telephone and Telegraph Company engineers in the preparation of Bell System Practices.

In addition, members of the Outside Plant Department represent the Laboratories in the activities of numerous safety committees of national organizations. Typical are L. S. Inskip's membership on the panels that prepare the National Electrical Code, Code for Protection Against Lightning, National Electrical Safety Code, and the author's membership on American Standards Association code committees for ladders and for rubber protective equipment for electrical workers.

The 105 test set. J. D. Apgar moves test set along a cable to locate faults in cable-conductor.

Also, of great importance is the Bell System liaison with the Underwriters Laboratories, which lists those items of power-operated telephone equipment involving safety of the public. This area of responsibility is handled by R. G. Watling.

An attempt has been made here to describe the activities constantly in progress to put the safest possible equipment in the hands of telephone workmen. As E. I. Green, former Executive Vice President of the Laboratories, said in a FORTUNE magazine interview, "We use every aid and trick we can find in our efforts to optimize the Bell System, but there is as yet no device that will substitute for good judgment." No truer words could be spoken on behalf of the engineer responsible for outside-plant equipment designed to play its part in the constant over-all Bell System effort to eliminate accidents.

Bell Laboratories engineers consider even the most precise laboratory tests to be only tentative indications of reliability in a new telephone. In carefully planned field trials, they study the performance of a new instrument under the rigors of its ultimate environment and test its appeal to the customer as well.

R. Black, Jr.

Field Testing An Experimental Telephone

Before new telephone apparatus is placed in service it must survive the crucible of rigorous testing. Often, a program of both laboratory tests and field trials is conducted before the apparatus is approved. Many tests made at the "drawing board" are a basis for accurately predicting its reliability and for judging the performance of myriad other factors prerequisite to its use in the Bell System. But because telephone apparatus is designed as a functioning component of a vast communications system, final proof of its reliability waits on evidence of its performance there.

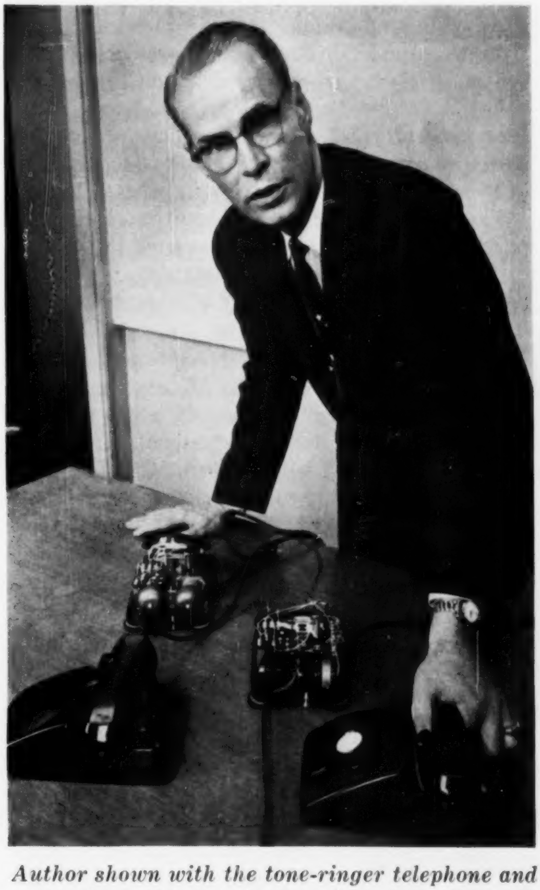
During a field trial of customer equipment—a new telephone, for example—a whole community, or some large segment of it, becomes in effect a laboratory. In this instance, the field trial is a study of the very important design criteria in the field of human factors, as well as a judgment on the efficacy of the instrument in a functioning system. Literally, we want to know how the customer reacts to the new telephone and, figuratively speaking, how it reacts to him. For these reasons, the same kind of creative thought is expended on planning a field trial as on the laboratory development of new apparatus.

If the trial is to be fully effective, precise control must be exercised over all its phases. This begins with the advance planning. The community chosen for the trial must be a representative cross section of the ultimate market in grades of telephone service and in environmental conditions. It may be necessary to design ancillary equipment, exclusively for the trial, to adapt the new apparatus to the existing central office without interruptions to regular service. Also, procedures must be formulated to train plant people and customers in the use of the new apparatus. The data to be gathered and the test procedures for its gathering are planned in detail; this may necessitate the formulation of new test arrangements. All these problems faced Bell Laboratories engineers in a recent field trial of the tone-ringer telephone. In following that trial, this article will tell the story of how some of these problems were solved.

The tone-ringer telephone (RECORD, *February*, 1957), designed to operate with the relatively low line current of the experimental Electronic Central Office, looks like the modern 500 set except for a louvered section in its side. Actually, it is a considerable departure from the bell-

equipped instrument. The most obvious change is implicit in its name—the tone ringer replaces the bell. This sounding method requires much less power than is needed to ring a bell; a transistor amplifier in the new instrument responds to a ringing tone of approximately one volt. A second transistor amplifier, in the transmitting branch of the set, permits operation on low values of talking current. Solid state devices—transistors and diodes—and other new devices such as ferrite coils were used extensively in the design.

Evaluation tests at the Laboratories predicted high reliability for the new telephone. What still had to be determined was: (1) its transmission quality in an actual operating environment, (2) the reliability of certain new components, (3) its general maintenance requirements, (4) the adequacy of its lightning protection devices and, of utmost importance, (5) if customers would benefit from the new set's transmission quality



Author shown with the tone-ringer telephone and a standard 500 set. Both casings have been removed to show difference in circuit components.

and if their speed in answering a tone-ringing telephone compared favorably with that for a bell-equipped instrument. Only a field test would yield the answers to these questions. The town of Crystal Lake, Illinois, was chosen for the purpose.

A number of factors were instrumental in the choice: the town's many classes of customers—farmers, professional people, local merchants, housewives, commuters; its various grades of telephone service, from private business to eight-party rural lines; and its several types of outside plant construction, including cable and open wire. Finally, the area's annual temperature range is from below zero to over 100 degrees and it experiences a full range of weather phenomena.

Special Trial Equipment

It is frequently prerequisite to a field trial either that special apparatus be installed to make the new equipment compatible with the existing central office or that special operating procedures be adopted. The last procedure is undesirable because it engenders additional training problems and because the most successful trials are conducted under normal operating conditions. The low-current nature of the tone-ringer telephone would have necessitated considerable revision in operating practices at the Crystal Lake manual office. To preclude this. Laboratories engineers devised special line circuits which made the low-current lines compatible with the manual office. Six bays of these circuits, transistorized tone-ringing generators (see photograph on page 17), a complete set of standby generators, and a special power supply composed the array of special central-office equipment.

Another problem indigenous to the low-current sets involved the outside plant. Plant operation with these low-current sets required a minimum outside-plant leakage resistance exceeding that required by the normal office, so cables containing the low-current lines were put under gas pressure and careful attention was given to tree trimming on the open-wire sections of these lines.

As a final preliminary to the actual trial, local installers were trained in the special handling of the new telephone. A school was established and a training manual was prepared which consisted of provisional installation and maintenance practices formulated at Bell Laboratories. Local central-office personnel also attended the school. This program led to effective coordination between the two groups of personnel when the lines used in the trial were converted to low-current operation.

More than 300 customers in the Crystal Lake office were selected as subjects for the test. Prior

to the conversion to low-current tone-ringing operation on the trial lines, at least one station on each trial line was visited. During this visit, transmission measurements were made from the station. These measurements included transmitting from the station to the central office, receiving, sidetone path loss at the station, line loss and received noise. These transmission measurements were made with a test arrangement devised for this trial. The equipment used consisted of a sound source, receiver coupler and indicating meter, and a noise measuring set.

Confirmation of Laboratory Tests

Similar transmission measurements were made at these same stations on every line after conversion to low-current operation. The improved transmission, which was predicted by prior laboratory measurements, was confirmed by the actual plant transmission measurements. The received noise on the new sets, which have no station ground, was so low that it was measurable at only a few stations.

To obtain comparative data a group of control lines was selected. The plant facilities supporting these lines were similar to those on the trial lines, though the telephone sets on the control lines were conventional.

To determine the stability of sets over a given time span, measurements of customer talking volume were made at intervals during the course of the trial on both trial lines and control lines. The distributions of these volume measurements at the start of the trial and about one year later indicated the good transmission stability of the new sets, as well as the old.

The speed of customer answering on both the trial lines and the control lines was recorded during the course of the trial. Customers with tone ringers answered their calls in approximately the same time as customers on the control lines with conventional bells. The percentage of incoming calls with "don't answer" varies with the season of the year. But in general, the percentage of "don't answer" calls on the trial lines and the control lines was the same.

Special routine measurements of several types were made in the Crystal Lake office during the course of the trial. All low-current lines were terminated in a jack field and line-leakage measurements were made from a special test desk during wet weather. Periodic measurements were made of current drains on all idle low-current lines. This idle-line current results from line-leakage and tone-ringer components bridged on the line. Abnormal current drains indicated a change in line or station conditions and often foretold a trouble report. Periodic checks were made of the frequencies, wave shapes and output levels of the tone generators. These tone generators met the design objectives for stability over the wide range of operating temperatures in the office.

The same testing arrangement used for field transmission measurements was used in the office to measure all low-current sets on an artificial line, prior to installation and after removal from

F. L. Crutchfield with special testing arrangements used in Crystal Lake trial. Mr. Crutchfield reads meter on control panel. Other components of the equipment are the sweep oscillator, rear; and the transmission measuring set, right.

service, either because of reported trouble or at the termination of the trial for customers who had used the sets for the trial period of one year.

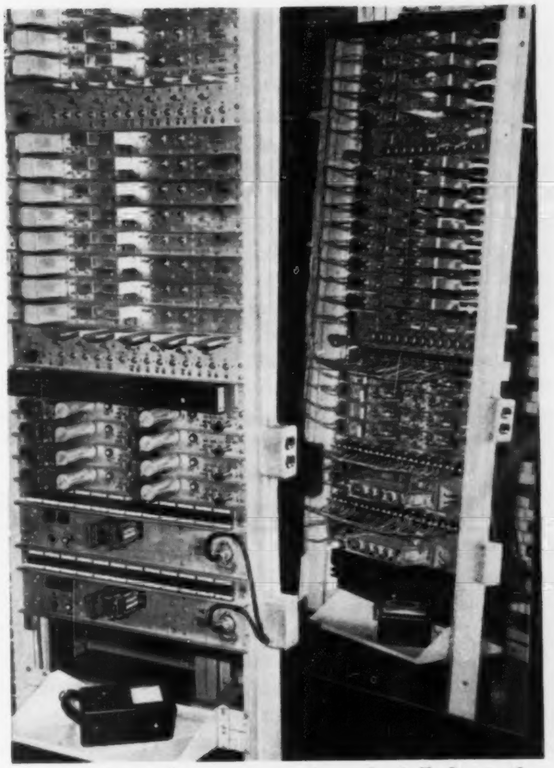
The photograph on page 16 shows the testing arrangement in use in the office. Tone-ringer output was also measured in the office with a specially constructed anechoic chamber (a chamber without echos). Some of these measurements were used to verify trouble reports. Units measured after a year of trouble-free service indicated that the low-current sets had stable transmission characteristics and stable tone-ringer output.

During the course of the trial, many of the low-current trial lines were subject to lightning surges as evidenced by the scoring of the carbon blocks and some blown fuses. The exploratory silicon-diode protector used in this trial in conjunction with the regular carbon-block station protector did an adequate protection job.

Resistance unbalance measurements were made on the trial lines and on the control lines after about a year of low-current operation. The amount of resistance unbalance on the low-current lines was approximately the same as on the control lines which indicates that low-current operation in an exchange plant with unsoldered pigtail joints introduces no new hazards.

A primary source of data in any station field trial is the line card, which is normally kept in the test center and reflects such factors as in-and-out movements, equipment changes, customer and employee trouble reports and located troubles. The line cards for the trial stations which are normally kept at a distant test center, were transferred to the Crystal Lake office where they were kept up to date. All trouble reports on these lines came into this office and all testing and dispatching on the low-current trial lines was handled from this office by assigned personnel. This arrangement made it readily possible to determine the required maintenance rate for the trial and control stations for any period of time.

In the early stages of the trial, after a little over half of the low-current sets had been installed, the station trouble rate was much higher than expected. These trouble reports were mostly "Bell Does Not Ring" or "Bell Does Not Ring Loud." Further installation was stopped and an analysis of the troubles was made. Two types of components—mylar foil capacitor and diodes—were not performing as expected. Design changes were made and installation of the new sets resumed. The trouble rate was appreciably reduced and the trial on all redesigned sets was continued for one year to prove the reliability of the low-current set and its components.



Bay of tone-ringer generators installed at the Crystal Lake central office. A mirror, tilted slightly, has been used to show the rear of the frame.

To show how customers in Crystal Lake reacted to the low-current tone-ringer set we will note briefly some of the information gained through interviews. Customers noticed the improvement in transmission and the quieter circuits; they liked the tone ringer; in fact most of them preferred the tone ringer to the bell. The reason given for this preference included: it was "less irritating," "more pleasant" or "kinder to the ears." Several said they had impaired hearing and could hear the tone ringer better than the bell. It took most customers about a week to become accustomed to the tone ringer. A few thought the tone ringer was not loud enough but agreed that they could hear it throughout the house and often in the yard. In general, interviews confirmed that the tone-ringer sets used in the Crystal Lake trial did an effective job of alerting customers to their incoming calls.

The reliability and effectiveness of the tone-ringer set at Crystal Lake was so well affirmed that it is now being used in the field trial of another important Laboratories development—the electronic central office in Morris, Illinois.

A meticulous test program is yielding promising data on new cathode materials for certain electron tubes. Very pure nickel with tungsten and magnesium additives may result in high-performance tubes that will last for many years.

H. B. Frost

High-Purity Nickel Cathodes: Performance Studies

The cathodes used in electron tubes consist of a base material—a nickel alloy—having a thin layer of oxides of the alkaline-earth elements. When heated to about 700°C, they emit the stream of electrons used in the amplification process. If a highly stable and reliable tube is required, as in an underwater repeater for a submarine cable system, the cathode must emit a steady, adequate supply of electrons for many years. It must not develop excessive internal impedance, and it must not evolve materials that could interfere with the operation of the tube.

In submarine cable systems, the trend is toward higher frequencies and greater bandwidths, which of course places stringent requirements on tube design. One of the main problems is to achieve a very-long-life tube with a high transconductance. That is, the tube must show a large change in plate current with a relatively small change in grid voltage.

A study was initiated in 1955 to find cathode materials suitable for such tubes. At that time, commercially available nickels were unsatisfactory; cathodes made from them could not sustain a high transconductance for a long period of time. Inadequate control of the composition of the nickel alloy frequently allowed the growth of electrical impedance at the interface between the alloy and its oxide coating.

Since commercial materials and methods were unsatisfactory, K. M. Olsen of the Metallurgical Research Department developed special methods for preparing ultra-pure nickels (RECORD, *February*, 1960). Since these materials were so extremely pure, single alloying elements could be added and studied individually, without the complication of having many impurities in the nickel (RECORD, *December*, 1960).

Even with the commercial nickels, of course, we are dealing with relatively pure materials. A good grade of commercial nickel typically has only between 0.01 and 0.1 per cent by weight of the ten or so elements of interest in cathode design. In the nickel strip prepared by Olsen, however, all elements were less than 0.005 per cent by weight —perhaps twenty times purer—except for the additives deliberately introduced.

Nominally, the compositions used in the cathode-development studies included a very pure nickel with no additives, and a series of seven alloys containing elements with the following concentrations: aluminum at 0.03 and 0.1 per cent; magnesium at 0.02 and 0.1 per cent; and tungsten at 0.2, 2.0 and 4.0 per cent. In addition, a commercial nickel (melt 85 of Inco 220) was used for comparison. The carbon and gas contents of this nickel were reduced by firing it in wet hydrogen.

For the tests, a special device designated the

M1935 electron tube was chosen because parts were readily available and also because this tube is sensitive to the important cathode properties that are necessary for the new submarine cable tubes. Structurally, it is quite similar to the Western Electric 435A tube used in the L3 coaxial transmission system. Its anode, however, is fabricated from molybdenum to reduce gas and contamination problems, and the control grid is modified to allow operation at lower voltages.

To study the effects of current density and operating temperature of the cathodes, as well as the effects of each additive, an experimental plan was developed in consultation with M. E. Terry of the Mathematics Research Department. In brief, this is the plan: Tubes were assembled in lots of nine, and for each tube in a lot, a different cathode material was used. This procedure minimized the variations due to the slight differences that are inevitable in fabricating and processing the tubes.

The nine tubes of a lot were distributed among three current densities and three cathode temperatures. For each cathode material, about 81 tubes were prepared and started on life test. The distribution, however, was not uniform over all test conditions. As shown in the Table (*see below*), the distribution was weighted toward the conditions that would yield the maximum amount of useful data. With about 81 tubes for each material, and with nine different test conditions, it is seen that over 700 tubes are in use in this part of the test program.

For each tube, ten different parameters are measured periodically during the life test. Many of these measurements are primarily to insure that the tubes are operating properly, but of most importance are the three parameters mentioned earlier: (1) transconductance, (2) total emission, and (3) the impedance in the cathode at the interface between the nickel and the oxide.

Transconductance at a fixed plate current, besides being the most important characteristic of a tube in a circuit, is a good indicator of the uniformity of the cathode and of the overall internal cathode impedance. These two parameters, however, cannot be separated on the basis of transconductance measurements alone.

For uniform cathodes, the second parameter—total emission—is an excellent measure of cathode quality. Finally, the interface-impedance measurements are also important to an adequate understanding of tube performance. Interface impedance is the most important part of the total electrical impedance of a cathode; it is that part which varies with frequency below 10 mc. For these three parameters, the ideal is to obtain a tube that for many years will have good emission properties, stable, high transconductance, and zero interface impedance.

The test methods used in this program are relatively conventional. The transconductance values are measured with a balanced bridge circuit using a signal frequency of 1000 cps. Total emission is measured with a pulse technique, which allows emission to be studied with little complication from other variables. In this test, the tube is arranged as a diode (plate, screen grid and control grid tied together). The pulses are 10 microseconds in duration at 20 volts, while the cathode temperature is reduced to about 620°C during measurement. Both the pulse voltage and diode current are measured on an oscilloscope.

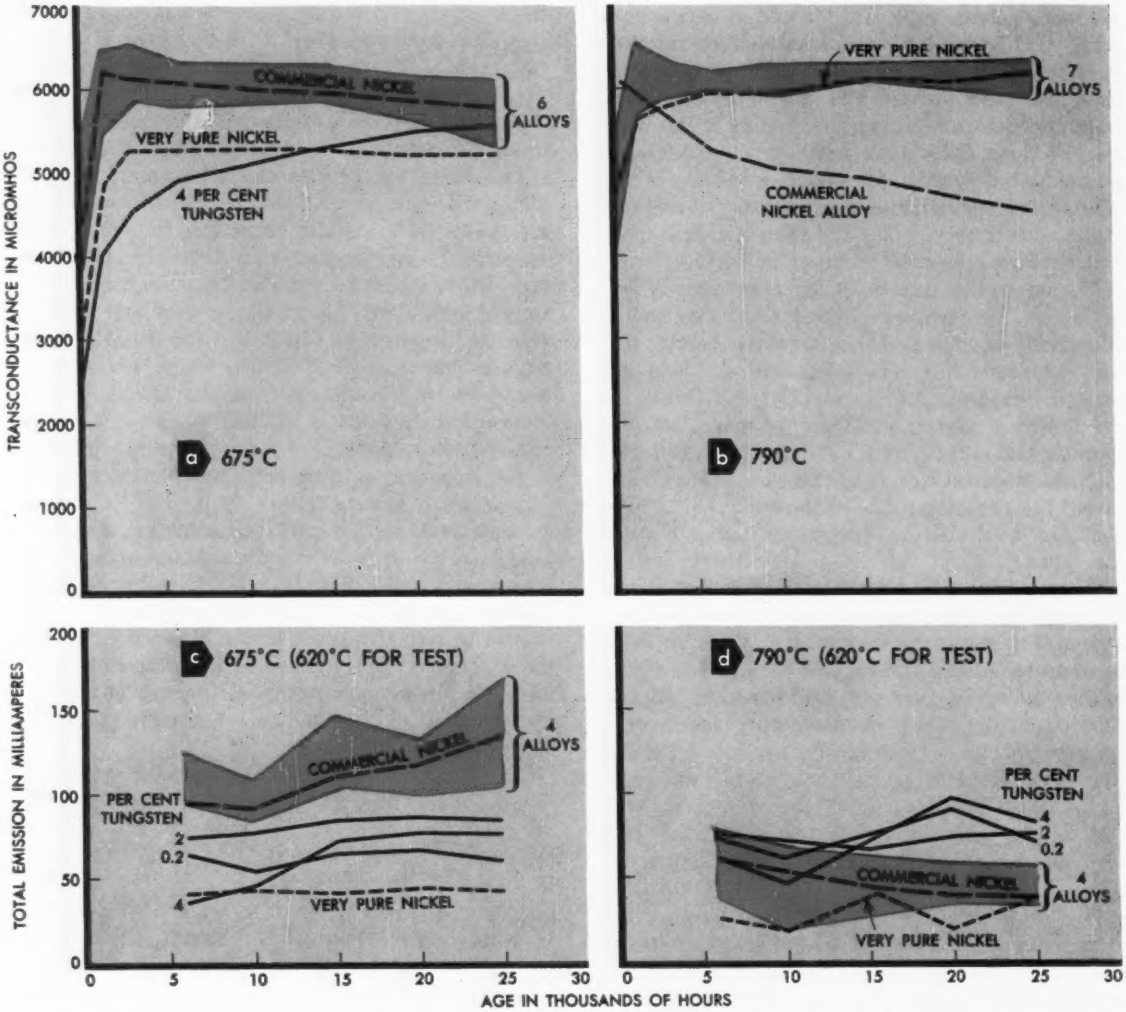
To measure cathode-interface impedance, a complementary network is used. The interface impedance is equivalent to a resistance-capacitance circuit, and the complementary network is a resistance inductance circuit. When the complementary network is adjusted to remove all variation in transconductance below 10 mc, the sum of the interface impedance and the complementary network appears as a pure resistance. The setting of the complementary network is used to calculate the interface impedance.

The graphs on the next page show some typical results of the tests for a period of 25,000 hours, or about three years. In these graphs, rather than show curves for all cathode materials, those that fall close together are grouped into bands, and only specific curves that depart significantly from the bands are drawn separately. All temperatures referred to are derived from optical pyrometer measurements and are true, not brightness, temperatures.

The first graph, a, shows transconductance at a cathode temperature of 675°C and a current density of 10 milliamps per square cm. All values fall within a narrow band except those for the very

Number of Tubes at Each Operating Condition for Each Alloy

Current Density in Milliamperes per square cm.	True Temperature in Degrees Centigrade		
	675°	733°	790°
5	5	5	5
10	12	17	12
20	10	5	5



Transconductance (a and b) and total emission (c and d) versus age in thousands of hours. Curves at left side are for a cathode temperature of 675°C. The curves at the right are for 790°C.

pure nickel and for the 4 per cent tungsten alloy. The fairly poor (that is, low) value of transconductance for the very pure nickel is consistent with its behavior under other conditions. The curve for the 4 per cent tungsten alloy shows that, although it has a low value for a long period, it later rises to the high values of the other materials. Graph b shows similar data at the higher cathode temperature of 790°C, but with the same current density of 10 milliamps per square cm. At this higher temperature, only the commercial nickel behaves poorly. Other materials, including pure nickel, maintain a high, stable transconductance.

Graphs c and d of the same illustration give data on total emission. They again refer to the 675°C and 790°C operating temperatures, respectively, but as mentioned earlier, the temperature is reduced to 620°C during measurement. Current density during operation is again 10 milliamps per square cm. The cures on these graphs begin at 6,000 hours because the test equipment was not available prior to this point in the test program.

With these graphs, it is important to compare c and d and notice that, while the tungsten nickels fall below the other alloys at the lower temperature, they are above the main grouping at the higher temperature. That is, the emission of the tungsten nickels is fairly stable at both temperatures, while the others fall to an undesirably low level at the higher temperature. The emission for very pure nickel remains low in both cases.

The next graph, shown on page 22, is typical of the measurements of interface impedance. At this temperature, 733°C, none of the specially prepared alloys shows any interface impedance. At the low temperature of 675°C, the tungsten alloys have some impedance in early life, but this quickly drops to zero. As seen in the graph, however, both the commercial and the very pure nickels are unacceptable for high-transconductance tubes. The commercial nickel has an interface impedance that increases monotonically—that is, continuously—with time. It also increases monotonically with operating temperature over the range studied. The ultra-pure nickel, by contrast, exhibits an initial peak at about 10,000 hours, followed by a gradual drop in impedance and a subsequent slight rise.

With the commercial nickel, the interface impedance is probably caused by the formation of a layer of barium orthosilicate between the oxide coating and the nickel base. This results from the presence of silicon in the base material. In the very pure nickel, the source of impedance is not well understood as yet. One clue is that there apparently is a correlation between the impedance and the moderately low cathode emission.

Among the alloys tested, those containing aluminum are a special case. They generally show sporadic interface impedance, which is not illustrated in the graph. This phenomenon has been traced mainly, if not entirely, to the oxide peeling or separating from the nickel. Peeled cathodes have been observed more commonly—23 cases—with the nickel containing 0.1 per cent aluminum, but the 0.03 per cent aluminum alloy has also resulted in 9 cases of peeled cathodes. Since peeling is a serious defect that causes short circuits between the control grid and cathode, aluminum alloys can not be considered for critical applications. None of the other alloys tested has shown any peeling.

The measurements of the other materials—the very pure nickel, the tungsten alloys, and the magnesium alloys—can be interpreted in terms of diffusion theory. According to this theory, the activity of a cathode, as measured by the total emission, is determined by how fast reducing agents arrive at the cathode coating. Such reducing agents come primarily from the underlying nickel, but the environment is also important. Small amounts of gas are inevitably found within the vacuum envelope of a processed tube. These gases may include both oxidizers (which usually damage a cathode) and reducing agents (which usually improve a cathode). They may therefore explain the emission characteristics of the very pure nickel. After a tube has had a few thousand hours on life test, it seems likely that gases are almost the only agents that could operate on a pure nickel cathode, since this material contains so little else besides nickel. Cathodes made with ultra-pure nickel have a low but quite stable level of emission.

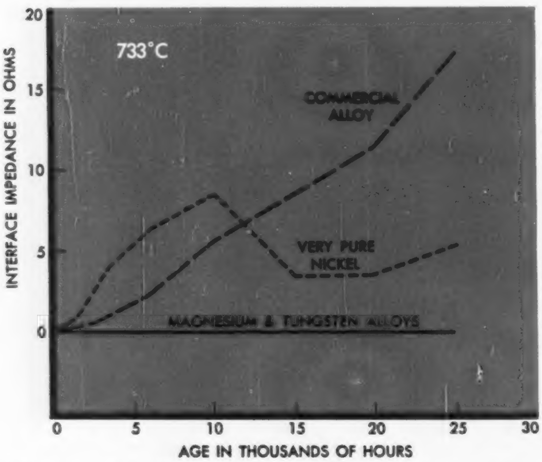
For the magnesium alloys, the situation is different. Magnesium can diffuse quite rapidly in nickel, and it can be lost from the nickel core both

The author (right) and R. C. Gee check the performance of high-purity nickel cathodes as revealed in life tests of tubes.

by reaction with the oxide coating and by evaporation from the bare nickel surfaces—that is, from the inside of the cathode sleeve structure in a tube. As a consequence, after 6,000 hours at 790° C, the 0.02 per cent magnesium alloy loses almost all its magnesium. Thereafter, it behaves very much like the pure nickel cathodes. The 0.1 per cent magnesium is only a little better, but at 675°C the diffusion is somewhat slower, so that more magnesium remains in the cathode core.

After 20,000 hours at 675°C, calculations and analyses indicate that, in the 0.02 per cent magnesium alloy, magnesium should be diffusing to the surface of the cathode at a rate of 10^{-9} micromoles (about 600 million atoms) per square cm per second. Even after 35,000 hours at 675°C, the tests show that magnesium is still an effective activator, but the results at 790°C indicate that the magnesium cannot be expected to last indefinitely. Even at the lower temperature, it may be exhausted by 50 to 100 thousand hours. Because magnesium diffuses so rapidly, the rate of diffusion to the surface has fallen off exponentially with time during most of the test program.

Tungsten, on the other hand, behaves quite differently from magnesium. Its diffusion constant in nickel is very much lower—about four orders of magnitude lower at 700°C—and since its evaporation rate is so low, it is lost from the core only by reaction with the coating. Also, G. E. Moore and H. W. Allison of the Chemical Electronics Research Department have shown that the rate of reaction, rather than the very slow diffusion, may limit the availability of tungsten as an activating



Commercial alloy and very pure nickel show undesirable impedance; magnesium and tungsten alloys are at zero. Aluminum alloys (not shown on graph) show sporadic impedance from peeling.

agent. This limitation means that the reduction rate may be even slower than indicated by the diffusion calculations.

All this implies that tungsten will become available as an activating agent only very slowly. This is a very desirable characteristic for tubes expected to last for many years, if the rate of arrival is adequate and if the tungsten is an effective reducing agent. Here the data on total emission, all taken at the reduced temperature of 620°C, become quite helpful. The data show that, after about 15,000 hours at a cathode temperature of 790°C, the total emission of the tungsten alloys is superior to that of all other materials. Although 790°C is too hot for long-life use, these accelerated data suggest that the tungsten alloys should be superior to the others after a much longer time of operation at lower temperatures. At the 675°C operating temperature after 25,000 hours, the total emission of the tungsten alloys is about the same as at the higher temperatures, and is significantly higher than the emission of nickel.

Tungsten alloys thus appear very promising, even though they do not have the high total emission values of the magnesium alloys at the lower temperatures. The tests at 675°C show that tungsten alloys require a long initial period for stabilization. This period is probably related to a gradual improvement in the internal environment of the electron tube as detrimental gases are absorbed and, perhaps, as any beneficial gases are released.

To avoid several thousand hours for stabilizing a tungsten-alloy nickel, additional alloys containing *both* tungsten (2 per cent) and magnesium (0.02 per cent) have been tried. Tubes using cathodes fabricated from this material have been under test for 25,000 hours, and they are showing excellent results. They seem to have the major advantages from both additives: the long life of the tungsten and the rapid stabilization of the magnesium.

These studies were conducted in the Electron Tube Development Department with close cooperation from Chemical Electronics and Metallurgical Research. They have demonstrated that nickel alloys for use in oxide-coated cathodes can have adequate emission over a long life, with no serious detrimental properties. Even though major modifications in manufacturing, particularly in the cleaning, aging, and exhaust processes, would be necessary before these tungsten-nickel and magnesium-tungsten-nickel alloys could be used in quantity production, they will be useful in new designs of submarine cable tubes and in other applications where very long tube life is desired.

Coordination, key to the success of a highly trained athlete, is an equally vital factor in the success of a complex organization. An example is posed by the U. S. Navy, whose ships, thanks to concepts developed at Bell Laboratories, now have the coordination needed to exploit fully their arsenal of modern air-defense weapons.

N. W. Bryant

Directing Naval Weapons

Weapon-Direction Equipment on naval ships, as the name suggests, is equipment that directs the guns and missiles against attack. Basically, it coordinates and expedites the operation of the various shipboard facilities provided for anti-aircraft defense. Under the "Mark 65" program (RECORD, *July*, 1960), Bell Laboratories has developed a number of weapon-direction equipments for various classes of ships of the U. S. Navy.

On a modern warship, the weapon-direction equipment is located in a weapon-control station. At that point, information on enemy targets is received from the ship's detection facilities—search and fire control radars and from persons acting as lookouts. Additional information from many other sources is received from the ship's "combat information center" which has an intricate internal and external communications system. The weapon-control equipment links together the rest of the defense equipment—fire-control directors, computers of various types; and, of course, the weapons. These are the facilities that must be properly coordinated for adequate defense against air attack.

To understand how these facilities work together, let us look first at some of the basic components of a modern air defense system, and then consider how the weapon-direction equipment coordinates these components for the best possible defensive action by the ship.

As noted above, a modern ship's defense equipment includes radars, fire-control directors, computers, and weapons. The radars may be divided into two groups—search and fire-control. Search radars survey the entire hemisphere above and around the ship. In doing this, they must continuously scan in all directions, and therefore cannot dwell at length on any one target. As a result, search radars cannot obtain continuous precise information on each target, and so are used only to detect targets and to obtain the approximate position and velocity.

The information from the search radars is displayed as a PPI picture. PPI stands for "Plan Position Indicator"—a map-like display of the surrounding area with "own" ship in the center. It shows all ships and planes within range of the radar in their relative positions. Approximate position, course and speed of targets are determined by following their movement on this display.

A ship's fire-control directors go a step further in treating targets. Specifically, they obtain precise information on targets that are to be engaged so that accurate gun or missile orders can be generated. Each fire-control director has a radar which can be assigned to an individual target, to

track it and to obtain precise information on its course, speed, and position. Individual assignments permit this radar to supply continuous information and thereby accurately keep up to date the target's position.

A ship's computers accept target data from the fire-control directors and generate accurate signals for controlling the guns. In many cases, orders may be generated simultaneously for several types of guns. Similarly, missile fire-control directors, with associated computers, work with missile launchers. In addition to providing launching information, these computers generate data for guiding the missiles in flight.

The combat information center, or CIC, is an area of the ship where all information on navigation, fleet operations, intelligence, and enemy action is gathered and presented. Here, liaison is maintained with the bridge of the ship, with the weapon-direction activities, and with all other friendly ships and planes. CIC delivers important information to the weapon-control station.

These are the major tools for air defense of a Navy ship. The Mark 65 Weapon-Direction Equipment was developed at the Laboratories to coordinate the use of these tools. The basic functions of the weapon-direction equipment can be divided into six major areas:

- Detect and track enemy targets,
- Evaluate the relative threat of the targets and determine the order of handling them,
- Assign targets to individual fire-control directors,
- Re-evaluate target threat on the basis of the more accurate tracking information from the directors,
- Assign weapons, and
- Initiate firing.

The equipment designed to accomplish these functions is shown in the block diagram *(see next page)*. It consists of operating and display consoles and various associated equipment cabinets.

There are three types of operating consoles: (1) radar-tracking consoles, where the operators track targets, *(see photograph above)*; (2) a director-assignment console, which displays the tactical situation along with information to assist in manual assignment of targets to directors; and (3) the weapon-assignment consoles, which display evaluation information to assist in assignment and firing of weapons, either guns or missiles. In addition, there are status panels that continuously show the current condition of all pertinent equipment.

Associated electronic equipment in the cabinets consists of sweep generators, electronic tracking circuits (or track channels), threat-evaluation computers, data-switching equipment, display-generating equipment, signal equipment and power supplies. Included there also are coordinate converters and facilities to perform the very important function of stabilizing the information to compensate for pitch and roll of the ship.

Naval personnel operate radar consoles during Mark 65 System trials aboard USS Northampton.

Operating personnel have several tracking consoles to observe PPI displays of air targets detected by the search radars. Normally, the primary search radar on a ship has a "pencil-beam" which rapidly scans up and down while it rotates around the horizon. This makes it possible to coordinate with the PPI display a second, or height display, which permits determination of target elevation. Associated with these displays are a number of electronic tracking channels in the cabinets. These tracking channels control symbols that appear on both the PPI and the height displays.

Each tracking channel generates dc voltages representing target position in three directions: X (east-west), Y (north-south), and H (height). The position represented by each track channel is indicated on the PPI and Height displays by a distinctive symbol. A "pantograph" on the PPI console controls the track channels. This mechanical device, and its controls, permit the operator to manipulate the voltages of any chosen track channel so that the symbols will be positioned on a target and will follow the target as it moves. As a result, the electronic tracking-channel circuit produces continuous voltages representing the target's position and speed in X, Y, and H.

These position and rate outputs of the track channels have several uses. First, this informa-

tion is essential for proper evaluation of target threats. Second, it provides a continuous up-to-date source of target data for use in guiding any selected director to the vicinity of the target so that it may locate the target and track it.

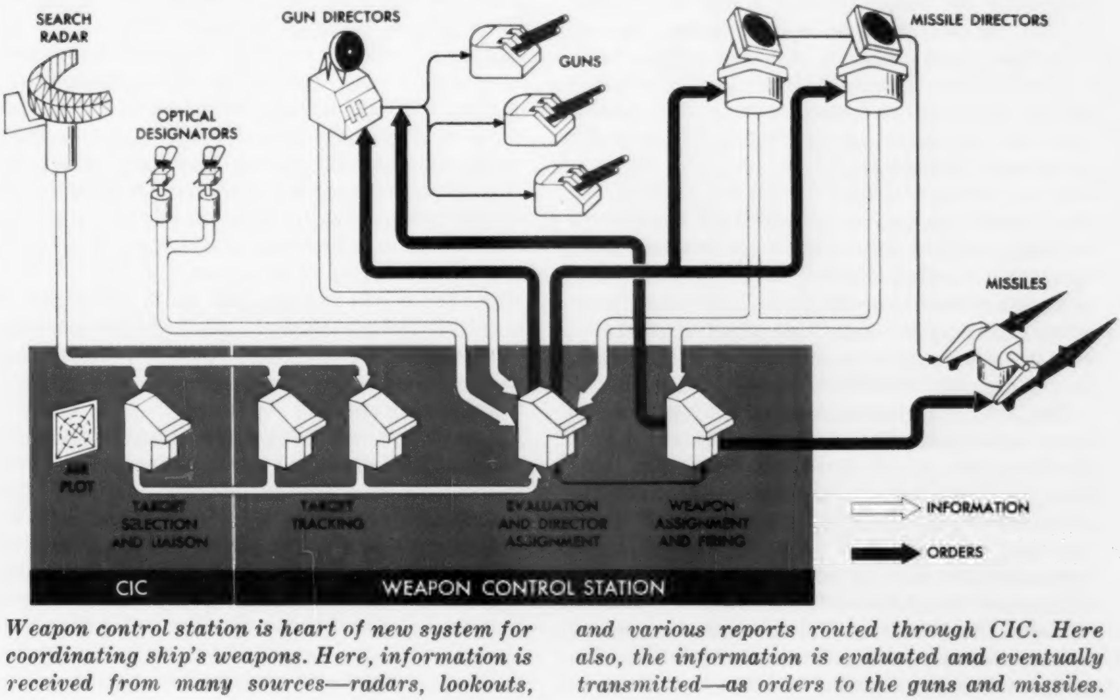
The threat-evaluation computer uses the information from the track channel to calculate to what degree a target is a threat. To do this, it determines range, bearing, elevation, and speed and computes the time for the target to reach an attack position. It determines when each target can be intercepted with the ship's weapons and considers which directors and weapons are most practical to use. It makes rapid calculations. In general, the computer considers all targets and all threats and takes all weapons into account to permit the best assignment of directors to targets.

All this necessary threat information is displayed at the director-assignment console for the use of the control officer. In some equipments, however, the threat-evaluation computer automatically assigns targets to directors by signaling and switching the track-channel information to them. In other equipment, the threat information is displayed only, and the control officer manually assigns targets to directors by switching the track-channel information to the directors he selects.

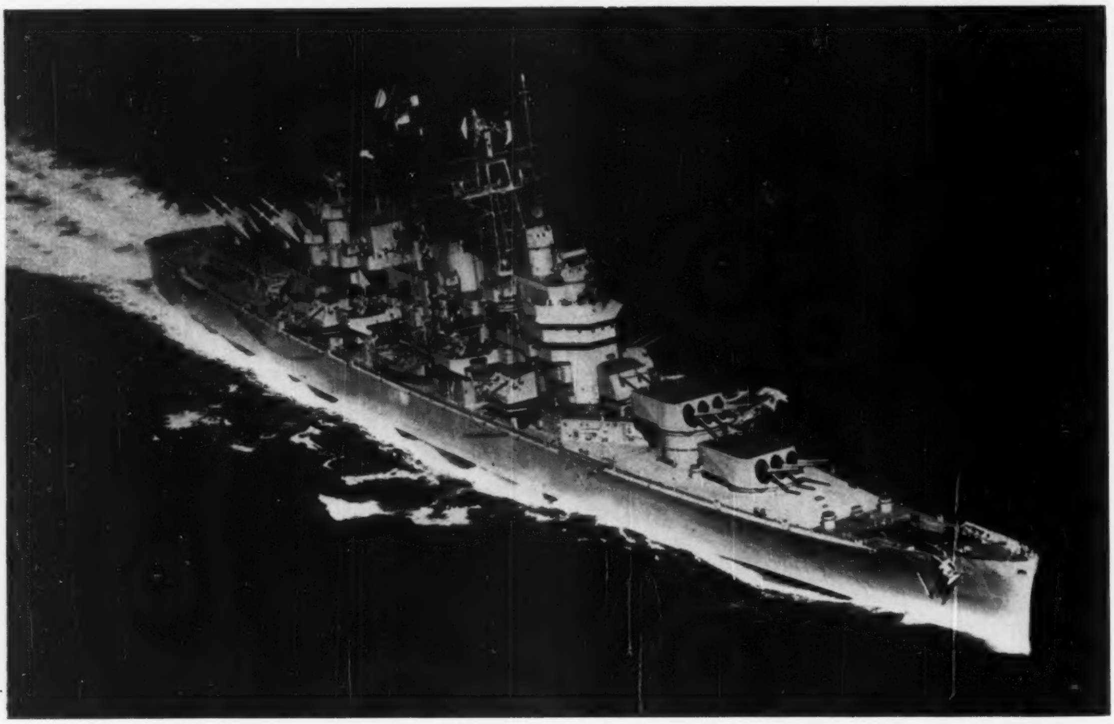
The director-assignment console also presents a tactical picture of the entire battle situation. Its primary display is a "synthetic" PPI picture in which the positions of all hostile targets are indicated by distinctive alphabetical symbols. Track positions of directors are also shown, but as distinctive numerical symbols. By observing this display, the weapon officer can see all threatening targets, note which have been assigned to which directors, and note the action each director has taken on its target. He also has a display of target-threat potentials as well as signals indicating when each director has located, and is tracking, its assigned target. This arrangement represents one of the major concepts of the Mark 65 system. For the first time in naval history, the weapon control officer can observe the complete tactical picture from one place on the ship—the weapon control station.

Since each fire-control director is assigned to a specific target, its radar can obtain continuous data on that target and thereby develop precise information on the target's position and velocity. This information is used in two ways. It is sent to the gun or missile computers which generate the signals that position the guns and missile launchers. It is also sent to the weapon-direction equipment where the relative threat of the target is re-evaluated, this time more precisely.

At the weapon-assignment console, there are displays that show continuously the position and course of each target being tracked by a director. For each target, this display also includes traces



Weapon control station is heart of new system for coordinating ship's weapons. Here, information is received from many sources—radars, lookouts, and various reports routed through CIC. Here also, the information is evaluated and eventually transmitted—as orders to the guns and missiles.



Portion of trials of Mark 65 Weapon Direction System were held aboard USS Boston. *This cruiser is equipped with a large number of directors and gun mounts and two Terrier missile launchers.*

indicating the maximum and minimum capabilities of the weapons with respect to intercepting the target. Since directors, and guns or launchers, may be unable to point effectively in all directions because of the ship's superstructure these limitations are also shown on the displays. Thus at the weapon-assignment console, the weapon officer is able to evaluate intelligently and quickly the situation, make the best assignments of weapons to targets, and give firing orders at the best time. This system makes it possible, for the first time, to switch weapons rapidly from one target to another and thereby concentrate the firepower successively on the targets of greatest threat when the "probability of kill" is highest.

The first coordinated weapon-direction equipment was evaluated several years ago on the *USS Northampton*, a task force command ship. This was a semi-automatic system for directing the fire of the five-inch and three-inch antiaircraft guns. The equipment controlled four fire-control directors and eight gun mounts. During this evaluation, operators at the tracking consoles manually initiated the tracks of the selected targets and monitored these tracks. From that point on, the equipment automatically designated targets to directors, and assigned the weapons for firing on those targets as they reached firing range. In many instances the required defensive action was carried out in one tenth of the time previously required. For the tactical picture and to permit close study, the *Northampton* installation included monitoring and manual "override" facilities.

Later, somewhat similar systems were installed on the guided-missile cruisers *USS Boston* and *USS Canberra*. These cruisers were equipped with a greater number of directors and gun mounts than the *Northampton*, and with two Terrier missile launchers. During these tests, the weapon-direction equipment coordinated and facilitated the defense against air attack for the first time using both guns and missiles.

The objectives of the Laboratories, to design an improved system for air defense of Naval ships, have been successfully met. A manifestation of the Mark 65 idea could be attested to by any pilot of a military plane that happened to come near one of those evaluating ships during the trials. Had he noticed, he would have seen *every* weapon on the ship pointing in his direction —a tribute to the concept of bringing all weapons to bear on the "most threatening" target.

Bell Laboratories outside plant engineers have developed a new dryer that cools and "squeezes" moisture out of ambient air. Thousands of miles of telephone cable now can be pressurized with dry air, thereby preventing or minimizing the detrimental effects caused by the entrance of moisture through minute flaws in the sheath.

J. M. Jackson

New Air Dryer for Pressurizing Cables

Paper insulates millions of miles of cable conductors in the Bell System. It is a "thirsty" material, absorbing any moisture that seeps through breaks in the protective cable sheath. Wet paper means lower insulation resistance, often accompanied by circuit trouble or outright failure. In most cases, however, if the pressure inside a cable is greater than the pressure outside, moisture cannot enter through breaks in the sheath.

Today, more than 100,000 miles of cable are maintained in a virtually moisture-free atmosphere by pumping several million cubic feet of dry air from central offices into cable networks each day. More than a ton and a half of water must be removed from this air before it is delivered to these cable systems. There are thousands of specially designed, air-drying units working around the clock to produce this immense volume of dry air.

While the service benefits obtained from pressurizing telephone cable systems with dry gas have been recognized for many years, it has only been during the last decade that dry air has been in general use for this purpose. In the earlier days of cable pressurization, dry nitrogen from tanks was used to charge toll cables (RECORD, *March*, 1934). Because of the high cost of supplying nitrogen in tanks, cable pressurization was limited to relatively leak-free cables on express routes with few, if any, branches or cable terminals. The higher revenue gained from the toll circuits, together with the importance of maintaining continuous service in such cables, justified the additional cost.

The excellent maintenance and service record established by gas-filled cables over the years created a growing interest in the development of apparatus and techniques for pressurizing exchange-cable systems. To make such pressurization more economical, Bell Laboratories engineers developed compressor-dehydrator apparatus to supply dry air, rather than nitrogen from tanks,

to vital cable networks (RECORD, *October*, 1956.)

Basically, the compressor-dehydrator consists of an air compressor, two drying towers filled with desiccant, and an electrically operated timer for switching the air supply from one tower to the other. The drying towers are used alternately; one dries while the other is reactivated. Reactivation consists of heating the used desiccant. This releases the adsorbed moisture, which is purged from the tank. Several hundred dehydrators of the adsorption type now provide satisfactory service throughout the Bell System. However, because of the many components required in this design of drying apparatus, the resulting assembly is relatively large, costly, and susceptible to troubles that require maintenance.

The New Air Dryer

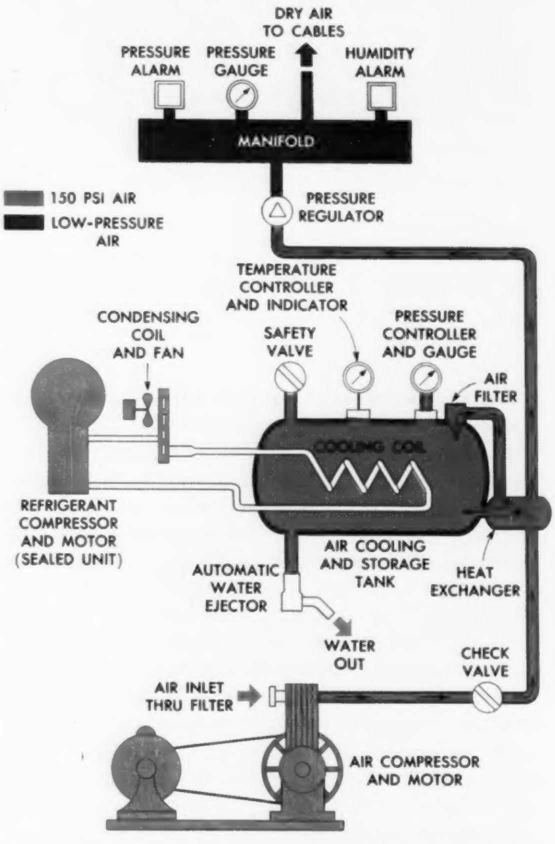
Outside-plant engineers at Bell Laboratories realized that there would be a growing demand from the Telephone Operating Companies for a less expensive and more compact drying unit that could be used for the rapidly expanding cable-pressurization program. They proceeded to develop a new unit employing the principles of compression, refrigeration, and expansion, rather than dynamic adsorption. This new unit consists of an air compressor, an insulated cooling tank containing a heat exchanger, a refrigeration system (similar to those used in kitchen refrigerators), and the necessary controls to regulate pressure and temperature within the tank. The pressure and dryness of the delivered air are monitored by high- and low-pressure and high-humidity alarms.

In operation, ambient air is compressed to several atmospheres, and delivered to the air storage and cooling tank, as shown in the system drawing at right. In the tank, it is cooled to an average temperature just above freezing. The refrigeration unit and evaporator coil, which are thermostatically controlled, maintain proper temperatures within the tank. Approximately 75 per cent of the moisture in the air is condensed in the form of fog or water as a result of the compression and cooling. The condensate is expelled periodically by an automatic water-discharge valve.

A further reduction in the moisture content of the air occurs during the expansion of the air as it passes from the high pressure maintained in the storage tank to that maintained in the cable system, usually 7 or 10 pounds per square inch. As a result of these dehumidifying processes, the air delivered to the cable system is at a relative humidity of less than 2 per cent at 70°F.

This process of moisture removal offers several advantages over the adsorption method. The most important of these is that the compression-refrigeration-expansion process is continuous—no cycling of drying towers or reactivation of a drying agent is required. This leads to another advantage: elimination of the need for a number of components with moving parts, such as electrical timers, heaters, and solenoid valves, which are subject to mechanical or electrical failure. The resulting apparatus is more compact, more economical to produce, and more efficient than the compressor-dehydrator.

Three standard sizes of refrigeration dryers are available: one with a rated drying capacity of 750 standard cubic feet per day (scfd), one with a capacity of 1500 scfd, and a larger unit with a capacity of more than 5000 scfd. The smallest unit is contained in a cabinet 22 inches wide, 15 inches deep, and 37 inches high. It is designed



Air-dryer system flow diagram. Ambient air is compressed to several atmospheres, cooled to a temperature just above freezing, expanded, and pressurized into the cable system at 7 to 10 psi.

Author J. M. Jackson checks pressure for refrigeration dryer designed for small central offices.

specifically for pressurizing the cable systems associated with community dial offices, toll repeater stations, and other small offices where the need for pressurization is relatively low and floor space is limited.

The intermediate capacity dryer shown above was developed for larger community dial offices and small central offices where air usage may exceed 750 scfd. This unit is identical in size, appearance, and operation to the smaller-capacity apparatus except that the air compressor and motor are larger.

The high-capacity apparatus is also completely self-contained, and is about twice as big as the other units. It is particularly applicable for pressurizing the many miles of subscriber cable usually associated with the larger central offices, where air usage, especially in the early phases of a pressurization program, may total several thousand cubic feet a day.

Development of the refrigerative-type air dryer greatly accelerated the pressurizing of exchange-cable plant throughout the Bell System. Telephone Operating Company experience in pressurizing these cables indicates potential annual savings of several million dollars by reduced cable maintenance along with better service to telephone customers.

2.5 Billions for Expansion and Improvement in 1961

News of the Bell System

In his year-end statement, Frederick R. Kappel, President of the A.T.&T. Company announced that the Bell System will spend two and a half billion dollars on service and improvement in 1961.

"America will keep growing in 1961," Mr. Kappel said, "and the Bell System is gearing itself to provide the enlarged facilities and the new and better means of communication America needs. This two and a half billion dollar program is the most tangible evidence we can offer of our confidence in the essential soundness of the economy and in the future growth of our industry."

Reporting on progress in 1960, the year-end statement noted a Bell System gain of 2,800,000 telephones, an increase of about 7 per cent in long-distance calling, extension of Direct Distance Dialing to half of the System's customers, and dial-operated telephones reaching to 97 per cent of the 60,700,000 in use at year's end.

In 1960 the Bell System played a major communications role in the success of NASA's Echo I satellite experiment. In the latter part of the year, the System outlined its plans to build and finance a series of satellites around the earth and applied to the F.C.C. for experimental frequencies to use in future tests of space communications.

Looking ahead to 1961 and beyond, Mr. Kappel envisioned growth in requirements for overseas facilities to handle voice, data, and television. "This need will be met," he said, "by an accelerated undersea-cable program as well as by space facilities. Within two years, we will have our own cable-laying ship to help us provide facilities faster."

Mr. Kappel said the field of business communications, including the rapid transmission of business data, will be a fast-growing one in 1961. "Our Data-Phone service, which allows business machines to 'talk' to other business machines across the country over regular telephone lines, already has good acceptance," he said. "We think it will play an even bigger role in business in the next few years.

"Another service improvement is the plan to provide unlimited inter-state calling within specified areas for a flat monthly rate," he added. "This plan will give many business customers who make many long distance calls more flexible telephone service designed to meet their specific needs."

E. I. Green Retires

Estill I. Green, executive vice president of Bell Laboratories, retired November 30 after a distinguished 39-year career with the Bell System.

Mr. Green has won nationwide professional recognition for his engineering achievements and for his contributions in the field of engineering management and administration. He has been granted more than 70 patents for his inventions, principally in the field of transmission. These include thermistor regulation, multipilot control, group modulation, frequency inversion at repeaters, the syllabic compander, and numerous other schemes and devices now in general use. He is the author of many authoritative articles on scientific subjects and on the management and evaluation of technical personnel. His writing is characterized by clarity and practicality of thought, coupled with felicity of expression.

His telephone career began in 1921 with the A.T.&T. Company's development and research department. There he engaged in transmission studies and the planning of new transmission developments, especially carrier telephone and telegraph systems. He took a leading part in the planning of the coaxial system. He also contributed to the standardization of carrier-system frequency allocations, which through the years has afforded large economies in development and manufacturing. The merger of the A.T.&T.'s development and research department brought Mr. Green to Bell Laboratories in 1934.

During World War II, some 250 designs of radar test gear—about half those required for the entire U.S. war effort—were developed under his general direction.

Following the war, Mr. Green returned to transmission work for the Bell System. He served as assistant director of transmission development and then as director of transmission apparatus development. In the latter post he was responsible for the development of a variety of system components and parts, including miniaturized electronic components compatible in size and performance with transistors.

In 1953 he was appointed director of military communications systems, with broad responsibilities for both planning and development work in that area. He became vice president—systems engineering in 1955 and for the next several years headed that part of the Laboratories engaged in the systematic analysis of and planning for future developments. He assumed the post of executive vice president in January 1959.

E. I. Green

Underlying his entire career has been a strong sense of values stemming from an understanding of people, technology and economics, together with a feeling for future needs and trends, and a faculty for decisive action.

A native of St. Louis, Mo., Mr. Green received the A.B. degree from Westminster College, Fulton, Mo., in 1915. After graduate study in mathematics, English and languages at the University of Chicago, he returned to Westminster as professor of Greek.

In World War I, he served overseas with the 89th Division and was commissioned a Captain in October 1918. After his discharge, he entered Harvard Engineering School and received the B.S. in E.E. in 1921. Immediately after graduation, he joined A.T.&T.

Mr. Green is a Fellow and Director of the American Institute of Electrical Engineers and a Fellow of the Institute of Radio Engineers, the Acoustical Society of America, and the American Association for the Advancement of Science. He has served as a member or chairman of many A.I.E.E., I.R.E. and A.S.A. committees. He is also a member of a number of other societies, and of the Research and Development Council of the American Management Association

Mr. Green is a Trustee of Westminster College, and in 1956 was awarded the Honorary Doctor of Science degree by that institution. His interests have ranged well beyond his primary field, and include, among other things, long-continued activity in field botany and wild-flower photography.

news in brief

William G. Pfann Wins Award of AIChE

The American Institute of Chemical Engineers (AIChE) recently honored William G. Pfann of the Metallurgical Research Department with the 1960 Professional Progress Award. The award, given "to recognize outstanding progress in the field of Chemical Engineering" was presented at the AIChE's annual meeting in Washington, D. C. last month. At that time, Mr. Pfann delivered the Professional Progress Award Lecture on "Zone Refining" and received a certificate and a $1000 honorarium.

He published the original paper on zone-melting techniques and a book on the subject in 1958. The concepts and developments which he initiated in this field are recognized as having great technical importance and are widely used.

In 1955, Mr. Pfann received the Mathewson Gold Medal of the American Institute of Mining, Metallurgical and Petroleum Engineers. He has also won the 1957 Francis J. Clamer Medal of the Franklin Institute and the 1958 Albert Saveur Achievement Award of the American Society for Metals.

Mr. Pfann joined Bell Laboratories in 1935, and did early work in the field of general microscopy. He later designed the prototype of the Type-A point-contact transistor and introduced procedures of electrical forming and etching used in its manufacture. He originated the gold-wire, alloy-bonding technique now widely used in transistor fabrication and also made early contributions to the development of atomic batteries.

With more than 35 patents on semiconducting devices and zone-melting techniques to his credit, Mr. Pfann is the author of more than 30 technical papers.

R. M. Bozorth Honored By Magnetism Group

At the Sixth Conference on Magnetism and Magnetic Materials, Richard M. Bozorth of the Physical Research Department recently received special recognition for his outstanding role in founding the Conference.

Mr. Bozorth, internationally known as a lecturer, consultant and author on magnetism, has been with the Laboratories since 1925 and with the Bell System since 1923. He originated the annual Conference on Magnetism and Magnetic Materials sponsored jointly by the American Institute of Physics and the American Institute of Electrical Engineers.

Mr. Bozorth has been chairman of the panels on Magnetic Research in the Defense Department and on Permanent Magnets under the sponsorship of the National Academy of Sciences—National Research Council.

Nike-Zeus Guidance System Successful

The guidance system for the Nike-Zeus antimissile missile, designed and developed at Bell Laboratories, proved successful in a recent test-firing at White Sands Missile Range, N. M.

Controlled commands were sent to the missile as it raced through the sky, and it responded to them to perform a planned turn in the trajectory. A complete tactical guidance system was carried in the missile.

The missile was fired by personnel from the Army, Bell Laboratories, and the Douglas Aircraft Company. One of the test objectives was to determine whether the missile's advanced aerodynamic design could withstand the tremendous pressures and structural forces resulting from its extremely high speed. The wingless Nike-Zeus missile design is designed to meet the exacting requirements for a missile to maneuver and move fast enough to intercept intercontinental ballistic warheads traveling at speeds above 15,000 miles an hour.

Facilities are being prepared in the South Pacific to test the Nike-Zeus system under tactical conditions. According to present plans, Zeus missiles launched and controlled from Kwajalein, in the Marshall Islands, will be pitted against Atlas ICBM's fired nearly 4,500 miles away at Vandenberg Air Force Base, California (RECORD, *December*, 1960).

New Postage Stamp Features Echo I

The United States Post Office honored the world's first communication satellite, Echo I, by issuing a 4-cent "Communications for Peace" stamp. The stamp was placed on sale in Washington, D. C. last month.

The Echo I postage stamp commemorates the historic launching of the balloon satellite last August, and the space communications project conducted by the National Aeronautics and Space Administration in cooperation with Bell Laboratories and the Jet Propulsion Laboratory.

Ralph Bown Receives High I.R.E. Award

Ralph Bown, retired vice president of the Laboratories, was named by the Institute of Radio Engineers to receive one of the organization's highest honors, the *Founders Award, 1961.* Mr. Bown is cited "for outstanding service to the I.R.E. and for outstanding contributions to the radio engineering profession through wise and courageous leadership in the planning and administration of technical developments which have greatly increased the impact of electronics on the public welfare."

Mr. Bown's career began in

1919 with the development and research department of the A.T.&T. Co.; at his retirement in 1956 he was Vice President in Charge of Patent Activities and Long-Range Planning at the Laboratories.

He is a Fellow of the Institute of Radio Engineers, and in 1926 received the Morris Liebmann Memorial Prize for his distinguished researches into wave-transmission phenomena. Mr. Brown served as President of the I.R.E. in 1927, and in 1949 received the Institute's Annual Medal of Honor for his leadership in Institute affairs and for his extensive contributions to the field of radio.

Laboratories Receives 1960 Industrial Science Achievement Award

The American Association for the Advancement of Science (AAAS) presented its annual "Industrial Science Achievement Award" to Bell Laboratories last month at ceremonies in New York City.

This award is given each year to the company that helped significantly to demonstrate one or more of the objectives of the Industrial Science Section of the AAAS. Included in these objectives is the "advancement of knowledge and the practical application of science in industry." The citation to Bell Laboratories was for its achievements in the field of universal communication during 1960.

Among the advances cited were: the successful experiments in long-distance communication by reflecting radio signals from the passive satellite, Echo I. These experiments were conducted in cooperation with the National Aeronautics and Space Administration (RECORD, *September*, 1960).

Another achievement cited in the award was the development of a new switching system which more than doubles the message-carrying capacity of existing submarine-cable facilities. Called TASI, an acronym for Time Assignment Speech Interpolation, the system was placed in operation between the U. S. and England in 1960.

Also mentioned was the world's first electronic telephone switching system, which was placed in full-time experimental service at Morris, Illinois, in November. Many complex electronic devices and systems, such as the temporary and semipermanent memory units had to be developed for this application.

The optical maser, a source of coherent light and a potential light amplifier, was used in preliminary communication experiments during the year. Communication over a modulated light beam should be especially useful in space communications, because its beams can be narrowly focused to permit highly directive communication.

Research on solid-state materials has also given rise during the year to new devices which may well revolutionize electronic technology in the future.

Command Guidance System Guides Tiros II Into Orbit

Bell Laboratories command-guidance system recently directed NASA's Tiros II weather satellite into its circular orbit. Developed for the Air Force Ballistic Missile Division for use in the Titan ICBM, the guidance system is produced by Western Electric.

This was the second successful use of this guidance system for the Tiros satellites. Using a Thor-Able launch vehicle, Tiros I was sent into its almost perfect circular orbit on April 1, 1960. Tiros II was carried by a Douglas-built Delta vehicle.

Other launches remaining in the Delta series also will be directed by the Bell Laboratories command guidance system. These launches include satellites and space probes.

New Cable Ship To be World's Largest

Bell Laboratories has developed entirely new concepts in the laying of ocean cable and rigid repeaters for the new Bell System cable ship. The ship, which will be the world's largest cablelayer, is scheduled to be completed in 1962. Specifications call for an over-all length of 512 feet, a breadth of 69 feet, and a capacity to carry some 1800 miles of deepsea cable. The ship will be powered by a turbo-electric system and have a cruising speed of 15 knots. It will have laying gear to handle the new two-directional cable and its repeater.

C. E. Schooley, Director of Operations of the Long Lines Department of A.T.&T. announced that "the ship will be built to lay newly developed telephone cable and amplifying equipment that require entirely new handling and laying methods. She will be equipped with laying gear designed by Bell Laboratories for the latest and most efficient cable-handling techniques."

Work on the design of essential features of the ship-cable and repeater stowage and handling equipment, new cable engines, overboarding facilities, and "payout" control systems began in 1953 and 1954 in the Transmission Systems Development Department. In early 1955, the Laboratories and Gibbs & Cox, Inc., a New York naval architectural firm, prepared study plans for the new cable ship.

Modifications of the "S.S. Fantastic," the full-sized, cable-ship mock-up at the Laboratories Chester, N. J., location, are now underway. These modifications will permit full-scale testing of the design to make final changes.

Special features will enable the ship to operate year-round in most weather conditions. For example, her hull will be strengthened for work in ice and her cable-handling deck will be enclosed.

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Rosenthal, C. W., *The Use of Computers as an Aid in the Design of Equipment for Digital Systems*, Fifth Annual Test Engineering Conf. Manual, i, pp. 1-1—1-14, Oct. 26, 1960.

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Thurmond, C. D., see Hannay, N. B.

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van Bergeijk, W. A., *Nomenclature for Devices Which Simulate Biological Functions*, Science, 132, pp. 1248-1249, Oct. 28, 1960.

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Wernick, J. H., and Geller, S., *Rare Earth Compounds with the $MgCu_2$ Structure*, Trans. A.I.M.E. Metallurgical Soc., 218, pp. 866-868, Oct., 1960

Wolff, P. A., *On the Spin Susceptibility of an Electron Gas*, Phys. Rev., 12-, pp. 814-819, Nov. 1, 1960.

Wolfstirn, K. B., see Fuller C. S.

PATENTS

Following is a list of the inventors, titles and patent numbers of patents recently issued to members of the Laboratories.

Abbott, G. F., Jr.—*Line Concentrator System*—2,962,555.

Budenbom, H. T.—*Compensated Hybrid Ring*—2,959,751.

Burton, J. A. — *Semiconductive Electron Source*—2,960,659.

Carbrey, R. L. and Feldman, C. B. H.—*Elastic Multiplex Speech Interpolation System* — 2,961,-492.

Cleveland, H. M.—*Surface Treatment of Semiconductive Devices* —2,961,354.

Crowley, T. H.—*Switching System*—2,962,552.

Cutler, C. C.—*Electron Discharge Device*—2,959,706.

Dickieson, A. C.—*Transmission Control in a Two Way Communication System*—2,958,733.

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Edwards, C. F.—*Wave Guide Joint*—2,962,677.

Ellwood, W. B.—*Contact Protection Arrangement*—2,958,809.

Elliott, S. J. and Keller, A. C.—*Telautograph Follow-Up System*—2,961,487.

Felch, E. P. and Sykes, R. A.—*Constant Frequency Source*—2,959,742.

Feldman, C. B. H., see Carbrey, R. L.

Flaschen, S. S. and Pearson, A. D.—*Glass Coating of Circuit Elements*—2,961,350.

Giger, A. J.—*High Speed Transistor Switch*—2,961,553.

Githens, J. A.—*Transistor Delay Circuits*—2,958,788.

Grant, D. W. and Wohlhieter, M. —*Winding Machine*—2,959,366.

Hagelbarger, D. W.—*Permanent Magnet Code Recording System* —2,958,568.

Herriot, D. R.—*Cathode Ray Tube Construction*—2,958,801.

Johannesen, J. D.—*Switching Circuit*—2,962,551.

Keller, A. C., see Elliott, S. J.

Lee, B. W.—*Transistor Circuit*—2,958,789.

Malthaner, W. A.—*Signal Delay System*—2,960,571.

Marcatili, E. A. J.—*Microwave Devices for Wave Guides of Circular Cross Section*—2,960,-670.

Mattson, R. H. — *Transistor Clocked Pulse Amplifier*—2,-961,551.

Ohm, E. A. — *Electromagnetic Wave Transducer*—2,960,671.

Ohm, E. A. — *Selective Mode Transducer*—2,961,618.

Pearson, A. D., see Flaschen, S. S.

Pierce, J. R.—*Scanning Antenna System*—2,959,784.

Pierce, J. R.—*Transmission at Reduced Bandwidth*—2,959,639.

Riesz, R. P.—*High Speed Rectifier*—2,959,505.

Rose, D. J.—*Gas Discharge Protector for Vacuum Systems*—2,958,803.

Ross, I. M. and Smits, F. M.—*Semiconductive Current Limiters*—2,959,504.

Schneider, H. A.—*High Speed Binary Counter*—2,962,212.

Smits, F. M., see Ross, I. M.

Sykes, R. A., see Felch, E. P.

Thomas, D. E.—*Automatic Direct-Reading Transistor Cut-off Frequency Measuring Set*—2,958,-824.

Wohlhieter, M., see Grant, D. W.

Wolfe, R. M.—*Pulse Signaling Circuit*—2,960,691.

TALKS

Following is a list of speakers, titles, and places of presentation for recent talks presented by members of Bell Laboratories.

A.I.E.E. FALL GENERAL MEETING, Chicago, Ill.

Baker, A. N., see Goldey, J. M.

Becker, F. K., *Digital Data Transmission Test Sets.*

Erwin, E. L., *Direct Distance Dialing of Telephone Calls in the Panel and No. 1 Crossbar Systems.*

Genke, R. M., and Mack, J. E., *A 16,000 Bit Temporary Memory for an Electronic Telephone Switching System.*

Goldey, J. M., Baker, A. N., Mackintosh, I. M., and Ross, I. M., *Dynamic Breakdown and Turn-Off Gain in p-n-p-n Switches.*

Mack, J. E., see Genke, R. M.

Mackintosh, I. M., see Goldey, J. M.

Ross, I. M., see Goldey, J. M.

Runyon, J. P., *The Derivation of Completely and Partially Specified State Tables.*

Smith, D. H., *Power Distribution, Conversion and Control for an Electronic Telephone Switching System.*

Ulrich, W., *Maintenance and Administration Methods in an Electronic Switching System.*

Unger, S. H., *Simplification of State Tables.*

FIFTH INTERNATIONAL CONGRESS ON HIGH-SPEED PHOTOGRAPHY, Washington, D. C.

Courtney-Pratt, J. S., *A High-Speed X-Ray Recording System.*

Courtney-Pratt, J. S., *High-Speed Photography Using a Sectional Lens.*

Courtney-Pratt, J. S., *Image Dissection Cameras.*

Courtney-Pratt, J. S., *A Lenticular Plate Multiple Picture Shadowgraph Recording System.*

Courtney-Pratt, J. S., *Some Unconventional Methods of High Speed Photography.*

OTHER TALKS

Adler, R., Ashkin, A., and Gordon, E. I., *Excitation and Amplification of Cyclotron Waves and Internal Beam Motions in the Presence of Space-Charge*, Eighteenth Annual Conf. on Electron Tube Research, University of Washington, Seattle, Wash.

Ahearn, A. J., *Mass Spectrographic Studies of Impurities in Solids and Liquids*, Stanford University, Stanford, Calif.; General Atomic, Division of General Dynamics Corp., San Diego, Calif.

Ahearn, A. J., *Mass Spectrographic Studies of Trace Impurities in Metals, Semiconductors, Insulators and Liquids*, So. Calif. Section of Soc. Appl. Spectroscopy, Los Angeles, Calif.; Sandia Corp., Albuquerque, N. Mex.

Amory, R. W., *Application of Computers to the Design of Communication Distribution Systems*, A.I.E./I.R.E., Portland, Ore.

Anderson, P. W., *Explanations of Various Experimental Phenomena Related to Superconductivity*, Theoretical Phys. Seminar, Princeton University, Princeton, N. J.

Andrews, F. T., Jr., see Emling, J. W.

Ansley, W. G., and Baker, A. N., *A High-Voltage, High-Speed, Three-Terminal p-n-p-n Switch*, PGED Conf., Washington, D. C.

Ashkin, A., see Adler, R.

Ashkin, A., see Gordon, E. I.

Baker, A. N., see Ansley, W. G.

Baker, D., *A Proposal for Modular Packaging of Transistor*

Resistor Logic (TRL) Circuits, 1960 W.E./B.T.L. Symposium on Printed Circuits, Greensboro, N. C.

Barney, H. L., *A New Transistorized Artificial Larnyx,* Am. Speech & Hearing Assoc. Conv., Los Angeles, Calif.

Barney, H. L., *Research and Development of the New Western Electric No. 5 Type Artificial Larnyx,* University of Pennsylvania Hospital Staff Meeting, Philadelphia, Pa.

Becker, J. A., *Seeing Individual Molecules of C_4H_4 in the Field Emission Microscope,* Franklin Institute, Swarthmore, Pa.; Sigma Xi Lecture, Georgia Tech., Atlanta, Ga.

Benes, V. E., *General Processes in the Theory of Queues,* Depart. of Statistics, Columbia University, N. Y. C.

Blanchard, T. G., *New Uses for an Old Device,* University of Kentucky, Lexington, Ky.

Bomberger, D. C., *The Engineer and Research,* Undergraduate Engineering Council, New York University, N. Y. C.

Bozorth, R. M., *Magnetic Properties of Some Superconductors,* Westinghouse Research Labs., East Pittsburgh, Pa.

Bricker, P. D., see Kersta, L. G.

Cagle, W. B., *Electronic Switching,* A.I.E.E. Communications Technical Gp. Session, Oklahoma City, Okla.

Cooper, H. G., see Kirkpatrick, W. E.

Coriell, A. S., *The Apparent Brightness of Short Flashes Measured by Sequential Matching,* Optical Soc. Am. Fall Meeting, Boston, Mass.

Courtney-Pratt, J. S., *A High Speed X-Ray Recording System,* Soc. Photographic Scientists & Engineers, N. Y. C.

Crowell, M. H., and Sears, R. W., *Electron Beam Tube for Analog-to-Digital Conversion,* Electron Devices Meeting, Washington, D. C.

Dacey, G. C., *Esaki Diodes,* Avco Co., Merrimack Valley Subsections of I.R.E., Wilmington, Mass.

David, E. E., Jr., see Kersta, L. G.

Donovan, P. F., see Miller, G. L.

Early, J. M., and Ross, I. M., *Epitaxial Semiconductor Devices,* I.R.E. Prof. Gp. on Electron Devices, Washington, D. C.

Edelson, D., Yager, W. A., and McMahon, W., *Some Novel Resonant Cavity Techniques for the Evaluation of Artificial Dielectrics. II,* Conf. on Electrical Insulation, Washington, D. C.

Eisinger, J., *Quantum Mechanics,* A.I.E.E. Meeting, N. Y. C.

Emling, J. W., and Andrews, F. T., Jr., *Transmission Aspects of Data Transmission,* Panel Discussion, National Electronics Conf., Chicago, Ill.

Engelbrecht, R. S., *Parametric Amplifiers: Historical Background and Recent Results with UHF Traveling Wave Amplifiers,* I.R.E., South Bend-Mishawaka Chapter, South Bend, Ind.

Epstein, M. P., *An Application of P-Adic Fields to Computing Techniques,* Soc. for Ind. & Appl. Math. Meeting, Philadelphia, Pa.

Flanagan, J. L., *Models for Approximating Basilar Membrane Displacement: II. Effects of Middle Ear Transmission,* Sixtieth Meeting of Acous. Soc. Am., San Francisco, Calif.

Flanagan, J. L., *Thresholds of Audibility for Periodic Pulse Trains,* Sixtieth Meeting of Acous. Soc. Am., San Francisco, Calif.

Foreman, B. M., see Miller, G. L.

Frishkopf, L., see Guttman, N.

Frost, H. B., *The Analysis of Residual Gas in Electron Tubes,* I.R.E. Prof. Gp. on Electron Devices, Washington, D. C.

Gerard, H. B., *Coincidence Achievement and Social Conformity,* International Congress of Psychology, Bonn, Germany.

Gerard, H. B., *Fear and Social Affiliation,* Am. Psychological Assoc., Chicago, Ill.

Geschwind, S., *Optical Detection of Paramagnetic Resonance in an Excited State of Ruby,* Syracuse University, N. Y.

Gibby, R. A., *An Evaluation of FM Data-System Performance by Computer Simulation,* International Symposium on Data Transmission, Delft, Holland.

Gibson, W. M., *Principles and Applications of Semiconductor Radiation Detectors,* Rensselaer Polytechnic Institute, Troy, N. Y.

Gnanadesikan, R., *A Plotting Procedure in MANOVA,* Am. Statistical Assoc., Pittsburgh, Pa.

Gordon, E. I., and Ashkin, A., *Transverse Wave Interaction on Electron Beams,* Eighteenth Annual Conf. on Electron Tube Research, University of Washington, Seattle, Wash.

Gordon, E. I., see Adler, R.

Guldner, W. G., *Special Problems of Gas Analysis,* Eastern Analytical Symposium, N. Y. C.

Gummel, H. K., see Smits, F. M.

Gupta, S. S., *The Gamma Distribution as a Possible Life-Length Model,* Statistical Reliability Analysis Section of Ind. Eng. Seminars, Cornell University, Ithaca, N. Y.

Gupta, S. S., *Single-Sample Procedures for Normal Means,* Statistical Decision-Making (The-

ory & Applications) Section of Ind. Eng. Seminars, Cornell University, Ithaca, N. Y.

Guttman, N., *Maximum Time and Intensity Differences for Clicks Inducing Lateralization*, Acous. Soc. Am., San Francisco, Calif.

Guttman, N., and Frishkopf, L., *Some Effects of the Prior on the Second Member of a Monaural Click Doublet*, Am. Speech & Hearing Assoc., Los Angeles, Calif.

Hamming, R. W., *The Cascade Method of Power Spectral Analysis*, Conf. on Variation of Electric & Magnetic Fields, University of California, Berkeley, Calif.

Hare, W. F. J., *Encapsulation of Silicon Diodes in Low Melting Glasses: Part II. Electrical Characteristics*, Electrochem. Soc. Meeting, Houston, Tex.

Harvey, F. K., and Schroeder, M. R., *Subjective Evaluation of Factors Affecting 2-Channel Stereophony*, Audio Eng. Soc. Meeting, N. Y. C.; Fifth Tonmeistertagung, Detmold, Germany; Sixtieth Meeting of Acous. Soc. Am., San Francisco, Calif.

Haynes, J. R., *The Role of Excitons in Recombination Radiation in Silicon*, General Electric Research Lab., Schenectady, N. Y.

Hershey, J. H., *Attainment of Reliable Product*, Institute of Radio Engineers Central Fla. Section & Brevard Engineering College, Patrick Air Force Base, Fla.

Hershey, J. H., *Reliability Considerations During Design and Development of Electronic Equipment*, Rutgers, New Brunswick, N. J.

Hight, S. C., *Communication & Control of Space Vehicles — Project Mercury*, I.R.E. Symposium, Greensboro, N. C.

Kadri, F. V., *Control of Frequency and Phase Displacement in Transistor Converter Circuits by Means of R-C Networks*, Sp. Tech. Conf. on Nonlinear Magnetics & Magnetic Amplifiers, Philadelphia, Pa.

Kalnins, I. L., and Pisarchik, A. P., *Encapsulation of Silicon Diodes in Low Melting Glass: Part I. Materials and Processes*, Electrochem. Soc. Meeting, Houston, Tex.

Kerney, I., *The Audio and Electroacoustics Committee of the Institute of Radio Engineers—Its Responsibilities and Methods of Operation*, 1960 Conv. of Audio Eng. Soc., N. Y. C.

Kersta, L. G., Bricker, P. D., and David, E. E., Jr., *Human or Machine? — A Study of Voice Naturalness*, Acous. Soc. Am., San Francisco, Calif.

Kirkpatrick, W. E., and Cooper, H. G., *A Barrier-Grid Tube for Binary Digital Storage*, Electron Devices Meeting, Washington, D. C.

Kisliuk, P., *The Passage of Electrons Through Metal Crystal Surfaces*, Phys. Colloquium, Pennsylvania State University, University Park, Pa.

Kisliuk, P., *The Reflection of Slow Electrons at Metal Crystal Surfaces*, Pennsylvania State University, Philadelphia, Pa.

Klauder, J. R., *On Rosen's Evaluation of Operators in Quantized General Relativity*, Princeton University, Princeton, N. J.

Knab, E. D., *Recent Advances in Solder Roller Coating Printed Circuit Boards*, Symposium on Printed Circuits, Greensboro, N. C.

Larkin, C. F., see Olsen, K. M.

Levenbach, G. J., *Life-Testing of Electronic Components*, Fourth Annual All-Day Forum on Quality Control, A.S.Q.C., University of Western Ontario Section & Hamilton Section, McMaster University, Toronto, Canada.

Levinson, J., *Fusion of Two-Component Flicker*, Optical Soc. Am., Boston, Mass.

Liehr, A. D., *Optical Activity in Rare-Earth and Transition Metal Complexes*, Am. Chem. Soc., Physical - Inorganic Section, University of Pennsylvania, Philadelphia, Pa.

Locke, W. J., *Microfilm-Savings with Quality—The Microfilming of Engineering Drawings at BTL, Murray Hill*, Am. Standards Assoc. Conf., N. Y. C.

Logan, B. F., see Schroeder, M. R.

Miller, G. L., Foreman, B. M., Yuan, L. C. L., and Donovan, P. F., *Application of Solid State Detectors to High Energy Physics*, Seventh Annual National Meeting of Prof. Gp. on Nuclear Science, Solid-State Radiation Detectors, Gatlinburg, Tenn.

Murphy, R. B., *Standards for Precision and Accuracy of Measurements and Their Relation to Standards of Quality*, Eleventh National Conf. on Standards, Am. Standards Assoc., N. Y. C.

Mason, W. P., *Internal Friction in Copper as a Function of Frequency and Temperature*, Acous. Soc. Am., San Francisco, Calif.

Matthias, B. T., *Rules of Superconductivity*, Wiesbaden, Germany.

May, J. E., Jr., *Longitudinal and Flexural Modes of Propagation in a Circular Bar: Numerical Calculations and Experimental Investigation*, Acous. Soc. Am., San Francisco, Calif.

McLean, D. A., *Tantalum Components for Microcircuitry*, National Electronics Conf., Chicago, Ill.

McMahon, W., see Edelson, D.

McSkimin, H. J., *Measurement of the Over-all Delay of Ultrasonic Delay Lines*, National Electronics Cong., Chicago, Ill.

Nichols, R. H., Jr., *Fluctuations in Short Range Propagation of*

Sound from a Fixed Source to a Fixed Receiver in Deep Water, Acous. Soc. Am., San Francisco, Calif.

Olsen, K. M., Larkin, C. F., and Schmitt, P. H., Jr., *Embrittlement of High-Purity Nickel*, Am. Soc. for Metals, Philadelphia, Pa.

Pfahnl, A., *Aging of Phosphors in Cathode-Ray Tubes*, Westinghouse Electric Corp., Bloomfield, N. J.

Pisarchik, A. P., see Kalnins, I. L.

Pollack, H. O., *Energy Distribution of Band-Limited Functions*, Math. Colloquium of National Bureau of Standards, Washington, D. C.

Pollack, H. O., *The Nature of Mathematical Research*, Franklin Institute, Philadelphia, Pa.

Rausch, J. M., *Microminiaturization*, Western Electric Co., Printed Circuit Symposium, Greensboro, N. C.

Rausch, J. M., *Micropackaging Discrete Components*, Fifty-Second Bumblebee Guidance Panel, Boston, Mass.

Rosenthal, C. W., *The Use of Computers as an Aid in the Design of Equipment for Digital Systems*, Fifth Annual Test Eng. Conf., Western Electric Co., Allentown, Pa.

Ross, I. M., see Early, J. M.

Schawlow, A. L., *Optical Masers*, Lehigh University, Bethlehem, Pa.; Johns Hopkins University Radiation Laboratory, Baltimore, Md.

Schlabach, T. D., *The Copper Etching Characteristics of Ammonium Persulfate Solutions*, Printed Wiring Symposium, Western Electric Co., Winston-Salem, N. C.

Schmitt, P. H., Jr., see Olsen, K. M.

Schroeder, M. R., *Correlation Techniques for Speech Bandwidth Compression*, Audio Eng. Soc., N. Y. C.

Schroeder, M. R., and Logan, B. F., *"Colorless" Artificial Reverberation*, Sixtieth Meeting of Acous. Soc. Am., San Francisco, Calif.; Fifth Tonmeistertagung, Detmold, Germany.

Schroeder, M. R., see Harvey, F. K.

Sears, R. W., see Crowell, M. H.

Sellers, G. A., Jr., *BLADES — The Bell Laboratories Automatic Design System*, I.R.E. Symposium, Greensboro, N. C.

Shulman, R. G., *Nuclear Magnetic Resonance in NiF_2 Domain Walls*, A.I.E.E. Magnetism Meeting, N. Y. C.

Singer, F. J., *Trends of Development in Telecommunication Services*, I.R.E. North Carolina Section, Greensboro, N. C.

Smits, F. M., and Gummel, H. K., *Lifetime Degradation in Silicon Under Proton Bombardment*, NASA Meeting on Radiation Damage to Semiconductors by High Energy Protons, Washington, D. C.

Snyder, L. C., *Jahn-Teller Distortions of Aromatic Molecules: A Molecular Orbital Description*, Princeton University Department of Chem., Princeton, N. J.

Stinehelfer, H. E., Sr., *Parametric Amplifiers*, Capitol Radio Eng. Inst. Alumni Assoc., Mountainside, N. J.

Strack, W., *BMEWS Communications*, A.I.E.E./I.R.E. Student Meeting, Ohio University, Athens, Ohio.

Sullivan, M. V., *A New Technique for the Preparation of Flat Germanium Surfaces*, Electrochem. Soc., Houston, Tex.

Sylwestrowicz, W. D., *Cleavage Fracture and Yield Phenomena in Silicon Single Crystals*, New York University, N. Y. C.

Sylwestrowicz, W. D. *Yield and Fracture Stresses of Silicon Single Crystals*, A.I.M.E. Fall Meeting, Philadelphia, Pa.

Tannenbaum, E., *Detailed Analysis of Thin Phosphorus Diffused Layers in p-Type Silicon*, A.I.E.E./I.R.E. Solid State Device Research Conf., Pittsburgh, Pa.

Tatsuguchi, I., *The Critical Dimensions in a UHF Printed Circuit Hybrid Junction*, Printed Circuit Symposium, Greensboro, N. C.

Theuerer, H. C., *Epitaxial Films of Silicon and Germanium by Halide Reduction*, Electrochem. Soc., Houston, Tex.

Uenohara, M., *Low Noise Fast Amplifiers*, International Congress on Instrumentation for High Energy Phys., Lawrence Lab., Berkeley, Calif.

Varnerin, L. J., *A Status Report on Tantalum Thin Film Circuits*, Printed Circuits Symposium, Greensboro, N. C.

Wannier, G. H., *Motion of Electrons in an Electric Field*, Joint Solid State Colloquium, Washington, D. C.

Weber, N. D., *My Experiences Since Graduation from RCA Institutes*, RCA Institutes, N. Y. City.

Weick, W. W., *The Current Carrying Capacity of Printed Circuits*, Western Electric Co. Printed Circuit Symposium, Greensboro, N. C.

Wertheim, G. K., *The Mossbauer Effect: Applications to Magnetic Materials*, Sixth Annual Conf. on Magnetism & Magnetic Materials, N. Y. C.

Yager, W. A., see Edelson, D.

Yuan, L. C. L., see Miller, G. L.

THE AUTHORS

John Forster was born in Vancouver, Canada, where he attended the University of British Columbia, receiving the B.A. and M.A. degrees in 1944 and 1946. After a period of teaching and research in semiconductors at Purdue University, he received the Ph.D. degree in Physics in 1953. Since joining the Laboratories in 1953, Mr. Forster has been concerned with the development of semiconductor devices and related problems, including development of point-contact and low-noise, alloy transistors, surface studies, and device reliability. At present he supervises a group concerned with development of semiconductor junction diodes for high-frequency and high-speed applications. In this issue he is co-author of "Diodes Can Do Almost Anything."

J. Forster

Robert M. Ryder was born in Yonkers, New York in 1915. He was educated at Yale—B.S. 1937, Ph.D. 1940, both in Physics, and then joined Bell Laboratories. He first worked on low-noise receivers for radars and then on fast amplifiers for early pulse-modulation experiments. Later, in vacuum-tube development, he worked on klystrons, planar triodes, and traveling-wave tubes, all for microwave uses. Since the early days of the transistor, Mr. Ryder has been concerned with the development of transistors and other semiconductor devices, especially some of the new types of diodes described in his article in this issue—"Diodes Can Do Almost Anything." He is a Fellow of the I.R.E.

R. M. Ryder

E. L. Alford, author of "Engineering for Safety in the Outside Plant," graduated from the University of Missouri in 1927 with a B.S. in Engineering. He joined the Laboratories that year as the first member of the newly formed Outside Plant Development Department recruited from outside the Bell System. Except for two years during World War II, when he was engaged in secret projects for the Armed Forces, his entire career has been devoted to the development of hand-tools used by the outside plant forces of the Bell System. His present supervisory responsibilities cover special tools and general safety matters in the Outside Plant Development Department. Mr. Alford has served as a member of the Laboratories Central Safety Committee since it was organized in 1951. He represents the Telephone Group (Bell System and Independent Companies) on American Standards Association Safety Code Committees concerned with rubber protective equipment for electrical workers and ladders. He is chairman of the American Standards Association Subcommittee for coordinating requirements for various types of ladders, and is a member of Eta Kappa Nu and A.I.E.E.

E. L. Alford

R. Black, Jr.'s association with the Bell System dates back to his high school days when, in his hometown of Bamberg, South Carolina, he spent Saturday afternoons climbing poles with a Long Lines crew. Since this job, which Mr. Black did "just for the experience", his professional life has been spent entirely at Bell Laboratories. Mr. Black received his B.S. in Physics from the Citadel in 1927 then spent two years on a fellowship at the University of Kentucky where he received the M.S. in 1929. He joined Bell Laboratories in that year as a member of the Transmission Instruments Engineering Department, where he worked on the development of special microphones for use in noisy locations, airplanes and battle-announcement systems. During World War II, Mr. Black was engaged in the development of hydrophones and sonar. For the past 12 years he has been con-

R. Black, Jr.

cerned with the design and development of station sets and instruments, first in the Apparatus Development Department and since 1954 in Systems Engineering. At present he supervises a group establishing requirements for ringing devices, dials—including rotary, reportory and pushbutton—transmission and a new coin-telephone set. Mr. Black is the author of "Field Testing an Experimental Telephone" in this issue.

H. B. Frost ("High-Purity Nickel Cathodes: Performance Studies") was born in Ft. Washakie, Wyoming. After three years service in the U. S. Navy during World War II, he was graduated from the University of Nebraska

H. B. Frost

with high distinction in 1948. He joined the Electron Tube Development Department after receiving the degree of ScD from the Massachusetts Institute of Technology in 1954. Since that time he has been engaged in studies of cathode performance and gas in

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electron tubes. Mr. Frost is a member of the Institute of Radio Engineers, Sigma Xi, Pi Mu Epsilon, and the American Institute of Electrical Engineers. In addition, he is a member of Committee F1A of the American Society for Testing Materials and the Committee on Electron Tubes of the I.R.E.

N. W. Bryant received the S.B. and S.M. degrees from Massachusetts Institute of Technology in 1930. His early work at Bell Laboratories was in research on voice-operated devices, including echo suppressors, compandors, and radio-telephone switching terminals. During World War II, he designed radars for use on battleships, cruisers, and submarines. Later, he was responsible for development of weapon-direction equipments for modern cruisers and guided-missile destroyers. His article in this issue, "Directing Naval Weapons", concerns this activity. At present Mr. Bryant is supervisor of a group concerned with design of digital data-processing equipment for Nike-Zeus. He resides in Chatham, N. J.

J. M. Jackson, a native of Fanwood, N. J., joined the Outside Plant Development Department of the Laboratories in 1942 and shortly thereafter entered the Navy, where he served until 1945. Upon his return from Naval service, he was associated with projects on joining and maintenance methods for telephone cables. During the Korean conflict Mr. Jackson was recalled to Naval service for two years. Since his return to the Laboratories in 1952, he has been engaged in the design of equipment for supplying dry air

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to cable systems, and waveguides and antennas for radio-relay networks. While working at the Laboratories, Mr. Jackson attended Rutgers University and was made a member of Technical staff in 1957. He is the author of "New Air Dryer for Pressurizing Cables."